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Jerusalem March 23rd - 27th 1992

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BSCE 21

JERUSALEM

March 23rd - 27th, 1992

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WORKING PAPERS

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13. ABSTRACT (Maximum 200 words)
The Bird Strike Committee Europe consists of civil and military participants from Europe with a common interest in the bird strike problem. Attendance is open to participants from other parts of the world. Annual Meeting Proceedings include Chairman's Report, Working Group Reports and Papers Presented:

TABLE OF CONTENTS:

14. SUBJECT TERMS
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4	Bird Strikes Problem in Ethiopian Civil Aviation	V.E. Jacoby and B.M. Zvonov, Russia	Statistics
5	The Diagnostic Significance of Thickened and Pronged Hamuli in Feathers	U. Frank and T.G. Brom, Netherlands	Bird Remains
6	Bird-Strike Remains Identification in India	S.M. Satheesan and R.B. Grubh, India	Bird Remains
7	Migratory-Bird Strike to Aircraft in India	S.M. Satheesan and R.B. Grubh, India	Plenary
8	Bird Strike Hazards to Helicopters	L.S. Buurma and A. Dekker, Netherlands	Plenary
9	The European Database of Military Bird Strikes from Proposal to Reality	A. Dekker and L.S. Buurma, Netherlands	Military Low Flying
10	The Potential of Lumbricide Chemicals for Use in Airfield Bird Control	J.R. Allan and L. Cordrey, UK	Aerodrome
11	The Influence of Tide and Wind on the Birdstrike Hazard at Costal Aerodromes	J.R. Allan and T.P. Milsom, UK	Aerodrome
12	Biotechnical Devices of Bird Scaring	V.Y. Biryukov and Z. Lapinskis, Latvia	Aerodrome
13	Improving Birdstrike Resistance of Aircraft Windshields	R.J. Speelman, R.C. McCarty and D.A. Dversdall, USA	Structural Testing
14	Bird Observation System Semmerzake	G. Dupont and R. Degrieck, Belgium	Remote Sensing
15	Radar CFAR Thresholding in Clutter under Detection of Airborne Birds	N.A. Nechval, Latvia	Remote Sensing

16	Determination of Number of Collisions between Aircraft and Birds to Control Risks of Erroneous Judgments on the Birdstrike Hazard	O.I. Panferova and N.A. Nechval, Latvia	Aerodrome
17	Determination of the Total Flying Rime Required for Testing the Performance of a New On-Airfield Bird Strike Presention Strategy against the Standard One	V.D. Ilyichev, Russia, and V.Y. Biryukov and N.A. Nechval, Latvia	Statistics
18	State of Affairs Concerning the Birdstrike Warning System in Central Europe	J. Becker, Germany	Military Low Flying
19	Collecting Efforts and Identification Standards in Relation to Bird Strike Statistics	T.G. Brom, Netherlands	Plenary
20	Note on the Performance of the Bird Control Service on French Airports	A. Berman, J.L. Briot and A. Eudot, France	Aerodrome
21	PICA – A Bird Strike Information Program	A. Eudot, France	Statistics
22	The Diversity of Featherprints in the Charadriformes and the Anseriformes	K. Perremans, Belgium	Bird Remains
23	A Trial to Establish if Observation of Bird Activity in the UK Using Airfield Radars Can Provide a Measure of the Bird Hazard	R.Ċ. McCloud, UK	Remote Sensing
24	Five Methods for Studying Nocturnal Bird Migration over Israel	H. Alfiya, Israel	Remote Sensing
25	Predicting Regularity of Bird Migration in Global Bottleneck Areas, on a Daily Seasonal and Yearly Scale, and its Implementation in Israel Air Force and Civilian Flight	Y. Leshem, Israel	Plenary
26	A Method of Identifying Bird Species from a Bloodstrain or Shred of Tissue	M. Hansen, Denmark	Bird Remains
27	Bird Strike Preventative Measures in Israeli Air Force	M. Sagi and J. Shamoun, Israel	Aerodrome
28	Radar studies on Bird Migration in the South of Israel	B. Bruderer, Switzerland	Plenary
29	Bird Strike Analysis in Estonia 1989–1991	J.E. Shergalin, Estonia	Proceedings
30	Soviet Bibliography about Aviation and Radar Ornithology 1990–1991	J.E. Shergalin, Estonia	Proceedings
31	Serious Bird Strikes to Civil Aircraft 1989–1991	J. Thorpe, UK	Statistics
32	Avian Community at Rome International Airport of Fiumicino. A Study for Better Facing Bird Hazard	A. Montemaggiori, Italy	Proceedings
33	Recent Publications on Birds and Aviation	J. Thorpe, UK	Plenary
34	An Annotated Bibliography of Bird Hazards to Aircraft	J.J. Short, USA	Plenary
35	Bird Strikes at Ben Gurion Airport, Israel, 1982–1991	Jerry Yashon and Eyal Shy, Israel	Statistics
36	Food Preference of the Chucker Partridge and Domestic Pigeon at Military Aerodromes in Israel	Batya Peled, Israel	Aerodrome
37	Risk Analysis of Bird Strikes on Vienna Airport	Klaus Krziwanek, Austria	Aerodrome
38	A Simple Risk Model for Assessing Bird Strike Potential	R.L. Merrit, USA	Statistics
39	Ultrasonics as a Method of Bird Control	D.M. Hamershock, USA	Aerodrome
40	Low-Level Airspace Bird Strike Evaluation and Using a GIS to Integrate Bird Population Dynamics into an Aircraft Bird Avoidance Model	David J. Ruben, USA	Military Low Flying
41	Evaluation of Shotgun Shooting to Reduce Aircraft Strikes by Laughing Gulls at John. F. Kennedy International Airport, 1991	R.A. Dolbear, USA	Aerodrome
42	Bird Strikes to US Air-Force Aircraft. 1987–1991	R.L. Merrit, USA	Statistics
43	Vultures in Spain	J.C. Marvelo, Spain	Military Low Flying
44	Substitute Bird Objectives and Constraints	J.-P. Devaux, France	Structural Testing

Invitation Letter

1. Bird Strike Committee Europe, Israel Nature Reserves Authority and Israel Airports Authority cordially invite you to attend the 21 meeting of BSCE, which will be held in Jerusalem, Israel.

2. Location of meeting

Sheraton Jerusalem Plaza Hotel
47 King George St.
IL-Jerusalem 91076
Israel

Telephone: 972-2-259111
Facsimilie: 972-2-231667

3. Address of the organizing committee

Dr. Eyal Shy
Nature Reserves Authority
78 Yirmeyahu St.
IL-Jerusalem 94467
Israel

Telephone: 972-2-388506, 387471
Facsimilie: 972-2-383405

Mr. H. Dahl
Civil Aviation Administration
P.O. Box 744
Ellebjergvej 50
DK-2450 København SV
Denmark

Telephone: 45 36 44 48 48 / extention 275
Telex: 27096 caa dk
Facsimilie: 45 36 44 03 03

4. Agenda

Registration of the participants will be held on 23 March 1992 between 0800 and 0900 local time.

Date	Afternoon	
Sunday 22 March	1800-2000	Steering Committee
Date	**Morning**	
23 March	0900-1200	Opening And Plenary
	Afternoon	
	1200-1330 1330-1700	Lunch Plenary
Date	**Morning**	
24 March	0830-1200	Statistics Working Group
	Afternoon	
	1200-1330 1330-1700	Lunch Military Low-Flying Bird Strike Working Group
Date	**Morning**	
25 March	0830-1200	Aerodrome Working Group
	Afternoon	
	1200-1330 1330-1700 1330-1700 1700	Lunch Aerodrome Working Group Testing Of Air Frames And Engines Working Group Steering Committee
Date	**Morning**	
26 March	0830-1200	Technical Visits
	Afternoon	
	1200-1330 1330-1700 1330-1700	Lunch Remote Sensing of Birds Working Group Bird Remains Identification Working Group
Date	**Morning**	
27 March	0830-1200	Plenary

5. Terms of Reference of BSCE

Bird Strike Committee Europe consists of civil and military participants from Europe with a common interest in the bird strike problem. Attendance is open to participants from other parts of the world.

Bird Strike Committee Europe shall:

a. collect, analyze, and circulate to all concerned data and information related to the bird strike problem in the European region;

   Note: This data and information should include the following:

   1. Civil and/or military data collections and results of analyses on bird strikes to aircraft.
   2. Results of any studies or examinations undertaken by states in the various fields related to the bird problem.
   3. Any information available in the field of design and structural testing of airframes and engines related to their resistance to bird strikes.
   4. Any other information having a bearing on the bird strike question and the adding to the various problems involved.

b. establish liaison on further research programme in order to avoid duplication;

c. study and develop methods to control the presence of birds on and near aerodromes;

d. investigate electro-magnetic wave sensing methods, e.g. radar, invisible light, etc., for observing bird movements;

e. develop procedures for the timely warning of pilots concerned where the existence of a bird hazard has positively been established;

f. develop procedures, if appropriate, for the initiation by air traffic control of avoiding action where the existence of a bird hazard has positively been established;

g. develop procedures enabling a quick and reliable exchange of messages regarding bird hazard warnings;

h. develop any material, e.g. maps, background information, etc., intended for inclusion in Aeronautical Information Publications;

i. aim at a uniform application throughout the European region of the methods and procedures and the use of material developed in accordance with c) to h) above,

provided suitable trials have proved their feasibility and monitor developments in this respect.

6. Terms of Reference of Working Groups

Aerodrome Working Group:

Exchange of information on methods used and results obtained from the work being done on aerodromes in order to minimize the bird problem at and around airports.

Military Low-Flying Bird Strike Working Group:

Exchange of actual data concerning medium and high intensity of bird migration as well as bird strike warnings (BIRDTAM) in a standardized format via the civil and military air traffic control or weather (WX) network, and implementation of bird hazard maps for the national civil and military AIPs.

Remote Sensing Of Birds Working Group:

Exchange of information on the use of radar and other sensors in the surveillance, identification and the risk assessment of bird presence and movements.

Testing Of Airframes And Engines Working Group:

Exchange of information on the methods of prediction, test methods and test results from:

(a) Bird impact reseach and development, design and testing of materials, structural specimens, wind-screen, engines, etc.

(b) Tests to show compliance with airworthiness requirements.

Bird Remains Identification Working Group:

Exchange of information on the methods used and the results obtained on identification of bird remains.

Statistics Working Group:

Collection, analysis, and circulation of data and information relating to birdstrikes.

7. Reception and Technical Visits

Will be announced at the beginning of the meeting.

8. Notification of participation

Participation in the meeting should be notified to the Chairman by filling out the attached paper, Appendix 1, and preferably before 1 January 1992.

9. Working Papers and Presentations

Working papers should contain references to proceedings of earlier meetings to avoid recapitulation of work done in the past and to further increase the continuity in the work.

Working papers should be sent to the Chairman of BSCE.

Working papers received before 1 February 1992 will be published in a bound set to be collected at the beginning of the meeting and papers arriving after 1 February 1992 will be published together with the report of the discussions and recommendations in the second part of the Proceedings of the meeting.

The Chairman will send a summary of working papers to the Steering Committee members to decide whether a working paper or a film or a video should be allowed to be presented orally or only included in the Proceedings, and if a paper or a film or a video will be allowed to be presented at the meeting, whether this presentation should be in the Plenary or in a working group. Working papers received by the Chairman after 1 March 1992 will only under exceptional circumstances be allowed to be presented orally and working papers received after 1 February 1992 will not be allowed to be presented at a Plenary Meeting. The Chairman of BSCE will send a copy of the full working paper to the chairman of the working group in question.

Under the assumption that participants to the meeting have already studied the working paper, the oral presentation of a working paper should be reduced to a summary of the paper, and not take more time than 15 minutes in order to allow time for discussion. English shall be used.

In order to obtain consistency of presentation, the following shall be observed:

Type:

Papers must have a good quality black print on A4 208 mm x 295 mm (8 1/4" x 11 1/2") paper with 20 mm margins on all sides to allow for printing and binding.

It will be advantageous to draw a box 20 mm in from paper edge on all sides on a blank sheet of paper to use as a guide behind pages being typed or wordprocessed. Due to problems with reproduction and readability, low quality dot matrix printing is not acceptable. Use mechanical lettering devises or adhersive transfer letters. Typewriter or computer lettering is generally not acceptable. Choose a medium-weight, simple typeface (e.g. Futura Mėdium, Helvetica or Courier), one that is not bold, ornate or compressed. Lettering should be of such a size that it will be about as large as text type (7-10 point) when reduced. The size of the lettering is simple to plan with 50% reduction of the illustration. For patterned lines and areas, printed adhersive tapes and sheets are preferable to handwork. For shading, use a pattern of lines or dots, not a solid tone. Make sure that lettering and patterns will not block up when reduced.

Format

Text should be single spaced with double spacing between paragraphs with text including new paragraphs being left (or both) margin jusitified.

Front Sheet

Each paper submitted should start with a front sheet as shown on the attached sample which at the top right hand has BSCE/21 then a space for the organisers to insert a WP number. Below this should be a brief summary of not more than 200 words, followed by some "keywords" for index purposes.

The body of the paper should be started on a new sheet.

Heading and Paragraph Numbering

All headings shall be left-justified and underlined (or bold if available). Section heading shall be in upper case and each section numbered /to .. Sub-headings shall be in upper and lower case and numbered 1.1, 1.2, etc. Sub-paragraphs may be lettered if desired. The above will make it easier to refer to paragraphs during discussions, etc.

Figures and Tables

All figures and tables should be titled across the top with "FIGURE" or "TABLE" in capital letters followed by the number. The title should follow on the same line in upper and lower case letters.

Photographs

Photographs must be sharp and of good contrast, showing details in important areas. Prints should be made from monochrome ("black-and-white") film whenever possible. If a colour transparency must be used, make the print from a custom-made monochrome internegative.

Page Numbers

Pages shall be numbered in light pencil at the bottom centre of each page. The organizers will renumber all pages when compiling the Proceedings.

If produced using word processing, the disc should be kept for possible use in producing the final report of the proceedings.

10. Hotel Reservations

Reservations shall be made not later than 20 February 1991 to

Sheraton Jerusalem Plaza Hotel
47 King George St.
IL-Jerusalem 91076
Israel

Telephone: 972-2-259111
Facsimilie: 972-2-231667

Please do not forget to mention in your order (on the envelope and inside) BSCE Meeting for special prices:

- Per person in a double room $ 55
- Single room $ 93
- Double room $ 110

The above-mentioned rates include breakfast and are subject to 15% service charge.

Please include in your order the following details:

First name, last name, kind of credit card, number of credit card, validity of card, and what kind of room you would like to order. Your order will be valid undtil two days before the meeting

after which a one-night fee will be charged if you choose to cancel it.

The below-mentioned hotels will be found in the neighbourhood (prices as per August 1991 and subject to 15% service charge):

King David Hotel ***** 23 Hamelech David St. Telephone: 251111	single room $ 170, double room $ 190
Laromme Hotel ***** 3 Zabotinsky St. Telephone: 697777	single room $ 107, double room $ 120
Windmill Hotel **** 3 Mendele St. Telephone: 663111	single room $ 69, double room 89

This hotel has restrictions such as public smoking on Saturdays

Ariel Hotel **** 31 Hebron Road (not within walking distance)	single room $ 63.25, double room $ 80

The local organizing committee has made arrangements for a one-day trip to the Dead Sea area on Saturday, 28 March 1992, at low cost.

Yours sincerely,

H. Dahl
Chairman

BSCE 20 / WP 14
Helsinki, 21-25 May 1990

TOWARDS A EUROPEAN DATABASE OF MILITARY BIRD STRIKES

A. Dekker and L.S. Buurma
RNLAF Flight Safety Division
P.O. Box 20703
2500 ES The Hague

ABSTRACT

The analysis of bird strike reports will only be a rewarding task when a multifold of biases can be avoided. In statistical terms this means that proper selections should be made. Depending on the questions to be answered the number of data available often is too small to achieve significant results. Therefore there is a strong tendency to lump data as much as possible. But as a result summary reports, such as those used in BSCE military statistics up to now, often cannot serve as comparison between countries and, even worse, are not suitable for reanalysing according to other criteria. The only way out is sharing the original bird strike forms while improving and standardizing the format. This report discusses a pilot study on the basis of 1988 data of six European Air Forces and gives some preliminary results.

BSCE Attendance

(to be sent to Mr. H. Dahl)
Civil Aviation Administration
Box 744, Ellebjergvej 50
DK-2450 Copenhagen SV - Denmark

Full name and full address: ....
....
....

Telephone number: ....
Fax number: ....
Telex number: ....

From organization: ....

will attend the 21 BSCE Meeting in Israel from .... to ....

I will attend

the Plenary meetings

and the working group sessions

Statistics **Bird Remains Identification** **Aerodrome**

Testing Of Airframes And Engines **Remote Sensing Of Birds**

Military Low-Flying Bird Strike

I will present a working paper dealing with ....
....

and will put up with the paper only being included in the Proceedings from the meeting

or prefer to have the paper orally presented in .... Working Group
the Plenary

A working paper which has not been received by the BSCE Chairman before 1 March 1992 will only under exceptional circumstances be allowed to be orally presented at the meeting and working received after 1 February 1992 will not be allowed to be presented at the Plenary Meeting.

I will be accompanied by my spouse at the meeting. YES ☐ NO ☐

I/we intend to participate in the trip to the Dead Sea area on Saturday, 28 March YES ☐ NO ☐

Terms of Reference of BSCE

(presented by BSCE Chairman)

The present Terms of Reference of BSCE are indicated in para. 5 of Working Paper 1 (Invitation Letter).

At the Steering Committee meeting on 23 July 1991, it was agreed to change the terms of reference as follows:

5. **Terms of Reference of BSCE**

Bird Strike Committee Europe consists of civil and military participants from Europe with a common interest in the bird strike problem. Attendance is open to participants from other parts of the world.

BSCE meets every even year in one of the European countries.

The Bird Strike Committee Europe shall:

a. collect, analyze, and circulate to all concerned data and information related to the bird strike problem in the European region;

Note: This data and information should include following:

1. Civil and/or military data collections and results of analyses on bird strikes to aircraft.
2. Results of any studies or examinations undertaken by states in the various fields related to the bird problem.
3. Any information available in the field of design and structural testing of airframes and engines related to their resistance to bird strikes.
4. Methods used and results obtained on identification of bird remains.
5. Any other information having a bearing on the bird strike question and the adding to the various problems involved.

b. establish liaison on further research programme in order to avoid duplication;

c. study and develop methods to control the presence of birds on and near aerodromes;

d. investigate electro-magnetic wave sensing methods, e.g. radar, invisible light, etc., for observing bird movements;

e. Develop procedures for the timely warning of pilots concerned where the existence of a bird hazard has positively been established;

f. develop procedures, if appropriate, for the initiation by air traffic control of avoiding action where the existence of a bird hazard has positively been established;

g. develop procedures enabling a quick and reliable exchange of messages regarding bird hazard warnings;

h. develop any material, e.g. maps, background information, etc., intended for inclusion in Aeronautical Information Publications; and

i. aim at a uniform application throughout the European region of the methods and procedures and the use of material developed in accordance with c to h above, provided suitable trials have proved their feasibility and monitor developments in this respect.

The reason for the changes are the need to stress the fact that BSCE should meet every second year and to minimize travel costs for the participants the meeting should take place within Europe. Further it has been found appropriate among the obligations of BSCE to include the work program of the Bird Remains Identification Working Group.

The meeting is asked to approve the proposal of the Steering Committee regarding the change of the terms of reference of BSCE.

Contact Persons Regarding Bird Strike Work

(Presented by BSCE Chairman)

1. Introduction

At the Steering Committe meeting in Frankfurt in July 1991, it was decided that there was a need for a revised list of persons to be contacted in connection with bird strike work in each country.

2. On the basis of replies received from persons appearing in former lists, notification of participation to the 21 meeting or correspondence with the Chairman the last years, the below persons may be considered as persons to be contacted in each country for bird strike subjects:

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3. The meeting is asked to note the working paper and inform the Chairman of any changes or errors before 1 May 1992 in order that a revised Working Paper may appear in the Proceedings from the meeting.

ADF 6

BSCE 21/WP 4

Jerusalem, 23-27 March 1992

BIRD STRIKES PROBLEM IN ETHIOPIAN CIVIL AVIATION

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ABSTRACT

In October-November 1990 authors in the staff of Russian - Ethiopian biological expedition were analyzed 110 serious bird strikes in Ethiopian civil aviation for period of 10 years, including the first in the world crush of passenger jet B-737 in 1988. It was inspected ornithological situation of 3 airdromes. The most of incidents occurred with jet B-707 (36.4%), B-720 (25.8%), B-767 (13.6%), B-737 (6.1%), turboprop DC_6 (7.6%). 42.0% of all strikes were recorded in September - October, 27.2% and 24.2% of them in November - January and in March - April respectively. 90% of strikes occurred between 6.00 and 14.00 hours. 54.1% of incidents took place on run out, 16.4% did on run away after touch . 85.7% of collision have happened bellow the level of 200 m. Their peak was in the 101-150 knots. Falconiformes were struck in 50% incidents, Columbiformes in 35,4% ones. It took place 10 collision and 12 engines were injured at airdrome Bole (Adis-Abeba) during 47 days period in September - November 1987. The damage came to 902,000$; the total one for 1987 did 1,200,000$. At airport Blair-Dar 15.09.1988 because of collision with *Columba guinea* has crushed B-737. It was killed 35 peoples. Standing detachment of 18-20 peoples near runway repelling birds from 6.00 o 14.00 hours giving decrease of bird strikes in Bole airport in 1988 to 1, in 1989 to 2, in 1990 to 2. Both the avifauna of airdrome localities and causes of birds and plane collisions were studied. It is given the recommendation for bird strike prevention of airdromes of Bole, Bahir-Dar and Dyre-Dau.

BSCE 21 / WP
Jerusalem, 23-27 March 1992

THE DIAGNOSTIC SIGNIFICANCE OF THICKENED AND PRONGED HAMULI IN FEATHERS

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ABSTRACT

The taxonomic distribution of thickened and/or pronged hamuli (hooklets) on distal barbules in the pennaceous part of feathers was studied with light microscopy (LM) and scanning electron microscopy (SEM) in order to assess the diagnostic significance of these structures. Comparison of the LM and SEM appearance of these structures indicates that thickened hamuli are artifacts, arising from the misinterpretation of rotated tape-like structures. Pronged hamuli, on the contrary, are non-artifacts. However, these structures have a much wider taxonomic distribution than was reported by earlier workers and prongs do not seem to be useful for identifying feather fragments.

Key Words: feather structure, SEM, pennaceous barbs, hamuli, prongs, diagnostic significance of feather structures

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INTRODUCTION

Recently, several characteristics in the microstructure of feathers have been studied to establish their diagnostic and phylogenetic significance (Brom 1986, 1990, 1991a, 1991b, Brom & Visser 1989). In this paper, the structure and taxonomic distribution of another ptilological characteristic, thickened and pronged hamuli, is evaluated.

Hamuli (or hooklets) are encountered in all avian taxa except the ratite birds (ostrich, rhea, emu, cassowary, kiwi, moa) - which have a loose feather texture - and may be considered basic components of the interlocking system of feathers (Wray 1887). They are located on the reverse edge of the distal barbules of pennaceous barbs (Sick 1937; Fig. 1 and 4) and contribute to the strength and cohesiveness of the vanes by locking into the recurved obverse edge of the proximal barbules of the adjacent barbs (Lucas & Stettenheim 1972: fig. 168; Dyck 1985: fig. 9).

In several taxa, thickened and pronged projections occur on the dorsal surface of the middle portion of the hamuli, which have been termed "kleine Spitzen" (Mascha 1904: 631), "prongs or horns" (Chandler 1916: 359), "Abstemm-Höcker" or "Abstemm-Dorne" (Sick 1937: 330), "pronglets" (Messinger 1965: 215), and "tiny pointed bumps" or "prickles" (Lucas & Stettenheim 1972: 249). It has been suggested that these prongs have the function of "fine-tuning" the proximal and distal barbules and hence, further increase the cohesiveness of the vanes (Sick 1937: 330).

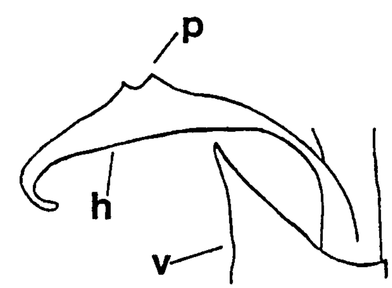
Earlier studies have suggested that thickened and/or pronged hamuli have a limited taxonomic distribution, which could mean that these structures might have a diagnostic significance.

Mascha (1904: 631, figs. 16 &17) encountered prongs irregularly distributed over the hamuli of the distal barbules of flight-feathers of two species of cuckoos, but did not find these structures in other taxa. Chandler (1916: 359, 364, figs. 69a, 67a, 72f, 72e) observed such prongs on distal barbules of contour feathers of pigeons and doves, and added that these prongs may sometimes be found on the hamuli of parrots and cuckoos. Furthermore, he depicted similar prongs on hamuli of the wandering albatross *Diomedea exulans*, and the crested guan *Penelope purpurascens* (Chandler 1916: fig. 10e & 46a respectively), but regarding the taxonomic distribution of prongs, he did not refer explicitly to these figures in the text.

Sick (1937: 329) depicted pronged hamuli in the rock pigeon *Columba livia*, the whooper swan *Cygnus cygnus* and reported their occurrence in several other taxa (Sick 1937: 366).

Messinger (1965: fig. 14) suggested that "pronglets" on the hamuli of flight-feathers distinguish the mourning dove *Zenaidura macroura* from the passenger pigeon *Ectopistes migratoria*, but he considered the thickening of the proximal-most hamuli typical of all Columbiformes (Fig. 1).

FIGURE 1. Schematical drawing of pronged and thickened hamulus in flight-feather of mourning dove - *Zenaidura macroura* (redrawn from Messinger 1965); h = hamulus, p = prongs, v = ventral tooth.



In summary, aforementioned light microscopy (LM) studies have reported thickened and/or pronged hamuli in albatrosses, petrels, ducks, swans, pigeons, parrots, and cuckoos.

Considering the - sometimes contradictory - descriptions of pronged and/or thickened hamuli and the fragmentary known taxonomic distribution of these structures, it is evident that the occurrence of these structures needs to be studied in greater detail. Might these structures be characteristic of the Columbiformes (cf. Messinger 1965), this finding would have diagnostic significance.

Pigeons and doves are notoriously dangerous with regard to flight safety and constitute a major category in bird strike statistics (e.g., Brom 1984, 1988). When identifying feather remains after collisions between birds and aircraft, the microstructure of the downy part of feathers is commonly used (e.g., Reaney *et al.* 1978, Laybourne 1984, Brom 1986). The columbids have highly characteristic downy barbules (Messinger 1965: 214, Brom 1986), but in case downy barbs are not available for examination, fragments of pigeon feathers may be more difficult to identify. Since the early publications by Mascha (1905) and Chandler (1916), hardly any studies have been dedicated to the morphology of the pennaceous part of feathers (cf. Dyck 1985). Therefore, diagnostic characters found in this part would facilitate the identification by providing an additional and independent character set.

In the present study, for the first time the morphology and taxonomic distribution of pronged and/or thickened hamuli is examined with scanning electron microscopy (SEM), and comparisons are made with LM observations.

MATERIAL AND METHODS

Feathers (mostly body-feathers) were plucked from study skins in the collection of the Zoological Museum Amsterdam (ZMA). Pennaceous barbs were removed from the rachis and the barbules were spread before mounting the barbs. For LM, the barbs were mounted dry between object glass and cover slip, which were glued together along the edges, examined with a Nikon Optiphot Biological Microscope, and photographed with the Microflex AFX photomicrographic attachment (dark box FX-35WA/FX-35W, Kodak T MAX 100 film) using a green-yellow filter. For SEM, the barbs were mounted on aluminium stubs using double-sided tape, coated with gold-palladium for 2-3 minutes, and examined with an ISI ds 130 scanning electron microscope (bottom stage, accelerating voltage 9 kV, working distance 20 mm.).

Feathers of the following species were examined (sequence follows classification as given by Wetmore 1960):

Tinamiformes: Tinamidae: solitary tinamou *Tinamus solitarius.*

Pelecaniformes: Pelecanidae: brown pelican *Pelecanus occidentalis.*

Ciconiiformes: Ciconiidae: black-necked stork *Ephippiorhynchus asiaticus.*

Anseriformes: Anatidae: Cuban whistling duck *Dendrocygna arborea*, chestnut teal *Anas castanea.*

Falconiformes: Accipitridae: golden eagle *Aquila chrysaetos.*

Galliformes: Megapodiidae: Nicobar megapode *Megapodius nicobariensis*, dusky megapode *Megapodius freycinet*; Tetraonidae: ruffed grouse *Bonasa umbellus*, ptarmigan *Lagopus mutus*, Phasianidae: bobwhite *Colinus virginianus*, grey peacock-pheasant *Polyplectron bicalcaratum*, pheasant *Phasianus colchicus.*

Gruiformes: Rallidae: king rail *Rallus elegans.*

Charadriiformes: Haematopodidae: oystercatcher *Haematopus ostralegus*; Scolopacidae: whimbrel *Numenius phaeopus*, bar-tailed godwit *Limosa lapponica*; Laridae: brown-hooded gull *Larus maculipennis*, black-headed gull *L. ridibundus*, sandwich tern *Sterna sandvicensis*; Alcidae: razorbill *Alca torda.*

Columbiformes: Pteroclidae: black-bellied sandgrouse *Syrrhaptes orientalis*; Columbidae: turtle-dove *Streptopelia turtur*, rock pigeon *Columba livia*, wood pigeon *C. palumbus*, blue-tailed imperial pigeon *Ducula concinna*, emerald-dove *Chalcophaps indica*, crowned pigeon *Goura cristata*, tooth-billed pigeon *Didunculus strigirostris.*

Psittaciformes: Psittacidae: Amboina king-parrot *Alisterus amboinensis*, hyacinth macaw *Anodorhynchus hyacinthinus*, Pennant's rosella *Platycercus elegans.*

Cuculiformes: Cuculidae: cuckoo *Cuculus canorus*, Klaas's cuckoo *Chrysococcyx klaas*, yellow-billed cuckoo *Coccyzus americanus.*

Strigiformes: Tytonidae: barn-owl *Tyto alba.*

Passeriformes: Corvidae: raven *Corvus corax.*

Our terminology of feather structures follows Chandler (1916) and Lucas & Stettenheim (1972).

RESULTS

In LM, the middle portion of hamuli may seem thickened (cf. Messinger 1965: fig. 14), but SEM observations clearly indicated that the widened or "thickened" appearance results from rotation or torsion of these tape-like structures (see Figs. 5-9). Pronged hamuli, in contrast, were found to be non-artifacts.

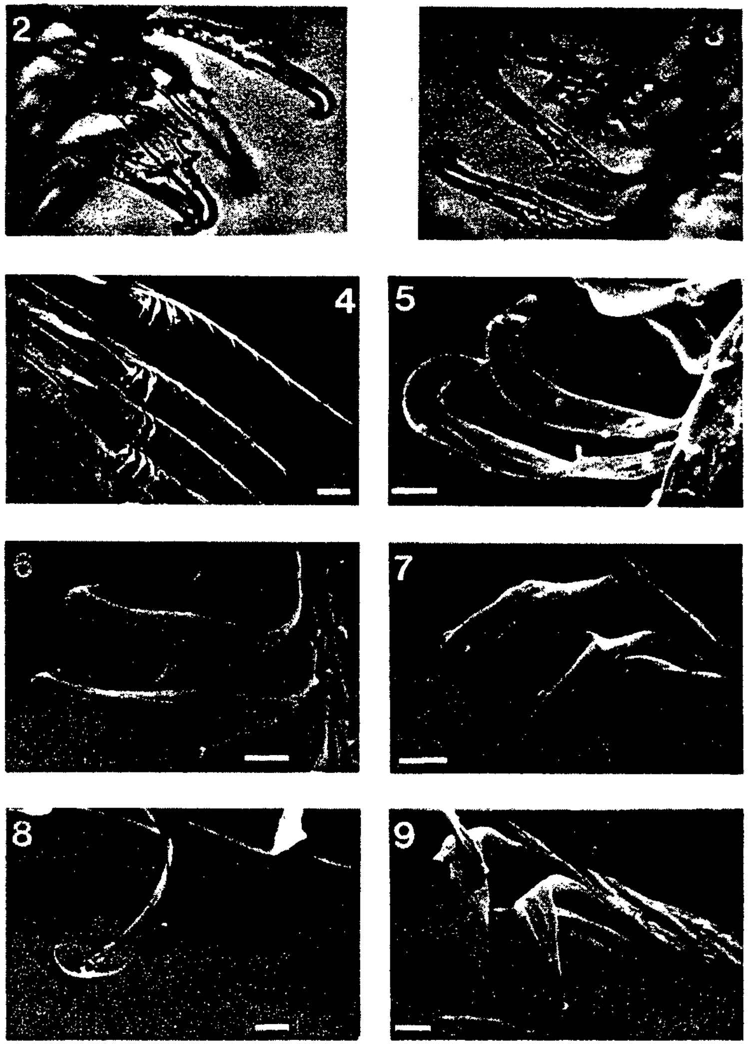
The number of prongs varied, but we failed to find any consistent differences with regard to their structure and frequency of appearance, both between hamuli of different feathers of a single bird and between different taxa. In one and the same barbule, both the number of prongs per hamulus (one to three, if present at all; Figs. 2-3) and the size of these prongs varied (compare, e.g., Figs. 6 and 8).

All variations mentioned above occur so irregularly, both interspecifically and intraspecifically, that neither functional nor taxonomic patterns could be discerned.

Actual prongs (non-artifacts) appear at one side of a hooklet, on the edge of the tape-like structure, look like a saw-tooth, and are usually orientated towards the hook's apex. The tape-like structure ensures that the relative positions of the hook and the prong, as they appear in LM preparations, are not fixed, due to the possible rotation (Messinger's "thickening") around the length axis. In LM preparations, prongs may seem to occur at both edges of the hamuli, but SEM examinations (e.g., Fig. 5) show that this condition is comparable to the "thickening" of hamuli: The direction of rotation determines whether the prong appears at the dorsal or at the ventral edge.

In LM, several artifacts may resemble prongs; SEM examination revealed that these may originate in different ways: It often happens, for instance, that a ventral tooth, which lies under a hooklet, gives the impression of being a prong on this hooklet (Fig. 9); conversely, actual prongs may look like a ventral tooth (Fig. 6).

FIGURE 2. Neck feather of blue-tailed imperial pigeon - *Ducula concinna*. Different numbers of prongs on hamuli of the same barbule (LM, appr. 1000 x).
FIGURE 3. Same feather (LM, appr. 1000 x).
FIGURE 4. Mantle feather of cuckoo - *Cuculus canorus*, distal barbules with pronged hamuli (SEM, scale bar = 28.0 µm).
FIGURE 5. Back feather of black-bellied sandgrouse - *Syrrhaptes orientalis*; due to rotation, prong appearing at ventral side of hamulus (SEM, scale bar = 4.4 µm).
FIGURE 6. Back feather of cuckoo - *C. canorus*; pronged hamuli of which upper prong seems to be underlying ventral tooth, but in fact is a true prong (SEM, scale bar = 4.6 µm).
FIGURE 7. Breast feather of pheasant - *Phasianus colchicus* (SEM, scale bar = 8.7 µm).
FIGURE 8. Back feather of raven - *Corvus corax* (SEM, scale bar = 6.0 µm).
FIGURE 9. Breast feather of oystercatcher - *Haematopus ostralegus*; true prong at the left, artifact - due to underlying ventral tooth - at the right (SEM, scale bar = 5.7 µm).



DISCUSSION

The occurrence of pronged hamuli corresponds well with Sick's (1937) findings. However, the sparse and irregular occurrence of pronged hamuli within a single barb puts their function of "fine-tuning" the distal and proximal barbules as was suggested by Sick (1937: 330) in doubt. The observation of pronged hamuli in all taxa examined implies that this characteristic has not the diagnostic significance as inferred by Messinger (1965). Prongs are widely but irregularly distributed among birds and it is clear that historically many ad hoc observations have been made proposing that thickened and/or pronged hamuli are of possible taxonomic significance. However, pronged hamuli apparently belong to the basic feather structure. These structures have a much wider taxonomic distribution than was reported by earlier workers and, therefore, prongs do not seem to be useful for identifying feather fragments. One may speculate that earlier in the evolutionary history of feathers they may have played a more prominent role and that they may have occurred in greater numbers, but that in extant birds these structures might be in the process of becoming reduced.

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REFERENCES

Brom, T. G. 1984. Microscopic identification of feathers in order to improve birdstrike statistics. In: M.J. Harrison, S.A. Gauthreaux & L.A. Abron-Robinson (eds) *Proc. Wildlife Hazards to Aircraft Conference and Training Workshop (Charleston)*: 107-119. Springfield: National Technical Information Service.

Brom, T. G. 1986. Microscopic identification of feathers and feather fragments of Palearctic birds. *Bijdr. Dierk.* 56: 181-204.

Brom, T. G. 1988. The analysis of feather remains: evaluation and perspectives. *19th Meeting Bird Strike Committee Europe (Madrid), Working Papers:* 341-356.

Brom, T.G. 1990. Villi and the phyly of Wetmore's order Piciformes (Aves). *Zool. J. Linn. Soc.* 98: 63-72.

Brom, T.G. 1991a Variability and phylogenetic significance of detachable nodes in feathers of tinamous, galliforms and turacos. *J. Zool., Lond.* 225: 589-604.

Brom, T.G. 1991b. *The Diagnostic and Phylogenetic Significance of Feather Structures.* Amsterdam, University of Amsterdam: 279 pp.

Brom, T.G. & Visser, H. 1989. The phylogenetic significance of the feather character 'flexules'. *Neth. J. Zool.* 39: 226-245.

Chandler, A.C. 1916. A study of the structure of feathers, with reference to their taxonomic significance. *Univ. Calif. Publ. Zool.* 13: 243-446.

Dyck, J. 1985. The evolution of feathers. *Zool. Scr.* 14: 137-154.

Laybourne, R.C. 1984. Identification of bird remains from bird-aircraft incidents by the microstructure of the downy part of the feather. *17th Meeting Bird Strike Committee Europe (Rome), Working Papers:* 282-284.

Lucas, A.M. & Stettenheim, P.R. 1972. *Avian Anatomy. Integument.* Agr. Handb. Forest. Serv. U.S. No. 362.

Mascha, E. 1904. Über die Schwungfedern. *Z. Wiss. Zool.* 77: 606-651, Taf. XXIX-XXXI.

Messinger, N.G. 1965. Methods used for identification of feather remains from Wetherill Mesa. *Am. Antiq.* 31: 206-215.

Reaney, B.A., Richner, S.M. & Cunningham, W.P. 1978. A preliminary scanning electron microscope study of the minute morphological features of feathers and their taxonomic significance. *Scanning Electron Microsc.* 1978; II: 471-478.

Sick, H. 1937. Morphologisch-funktionelle Untersuchungen über die Feinstruktur der Vogelfeder. *J. Orn.* 85: 206-372.

Wetmore, A. 1960. A classification for the birds of the world. *Smithson. Misc. Coll.* 139 (11): 1-37.

Wray, R.S. 1887. On the structure of the barbs, barbules, and barbicels of a typical pennaceous feather. *Ibis* (5th series) 5: 420-423.

BIRD-STRIKE REMAINS IDENTIFICATION IN INDIA

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ABSTRACT

Since 1966 the Bombay Natural History Society started receiving bird remains from Indian aerodromes. Since 1980 with the sponsorship of Aeronautics R & D Board of India (Ministry of defence), the BNHS has launched a major ecological study of bird hazard at 22 aerodromes and also started receiving bird strike remains for identification from a larger number of aerodromes on a regular basis. Seventy species of birds and three species of bats have been identified from bird or animal remains from 1966 to 1991. Analysis of 460 bird and bat remains revealed that birds of prey have caused 56% of the incidents of which *Milvus* kites formed 25% and vultures 23% topping the list of problem birds. Some of the other birds encountered by aircraft were pigeons and doves, ducks, egrets and herons, cranes, sandgrouse, lapwings, stone curlew, peafowl, crows, rollers, gulls, mynas and starlings as well as swifts and swallows. More than 50% of the birds and bats which hit aircraft in India weighed from half a kg to five kg.

INTRODUCTION

Since 1966 the Bombay Natural History Society has assumed a pivotal role in the national bird strike prevention programme assisting the civil and military aviations in India through identification of bird remains and suggesting ecological methods to reduce bird menace to aircraft. As a part of this study the BNHS also has been receiving bird remnants along with bird-strike data from aerodromes. The following is a report on the identification of bird-strike remains handled by the BNHS from 1966 to 1991.

MATERIALS AND METHODS

The BNHS has prepared a national bird-strike reporting form by incorporating all categories of questions included in the ICAO bird-strike repoting form, together with ICAO computer codes It also includes some additional questions relevant to the Indian situation. Bird and other animal remains accompanying data were cleaned first with warm and diluted detergent and then rinsed repeatedly with cold running water and dried using an air blower before examination. Investigation to identify the species consisted of comparing the samples macroscopically and microscopically with bird and bat skins present in the Collections of the BNHS. Standard methods used by others for microscopic identification of feathers were used (Brom & Buurma 1979, Brom 1980, 1991, Laybourne 1984 and Rosalind and Grubh 1987).

RESULTS AND DISCUSSION

By the end of 1988, 60 species of birds and three species of bats were identified from bird-strike remains (Grubh 1989). By 1990, 7 more species of birds were added to the list (Satheesan 1990, Satheesan, Grubh & Pimento IN PRESS). By the end of 1991 the figure rose to 73 species of birds and three species of bats from a total of 460 bird remains (TABLE 1).

Out of 460 incidents 55.97% was caused by raptors or birds of prey. 25.44% of the strikes were caused by *Milvus* kites and 22.82% by vultures, the two groups of birds causing extensive damage to aircraft in India. As individual species the Pariah Kite *Milvus migrans govinda* responsible for 25% of th and the Whitebacked Vulture *Gyps bengalensis* for 17.8%, were a greater menace to flying aircraft. Till 1988 the number of vulture hits to aircraft (23.78%) was more than kite hits (16.29%) as revealed by analysis of 307 bird and bat strikes where the species were identified from remnants. Other birds encountered

TABLE 1. Bird and bat species identified from aircraft strike remains in India from 1966 to 1991 (n = 460)

Species	c wt in g	No. of cases	%
(A) Birds			
1 Pond Heron *Ardeola grayii*	215	1	0.22
2 Cattle Egret *Bubulcus ibis*	450	4	0.87
3 Little Egret *Egretta garzetta*	400	1	0.22
4 Night Heron *Nycticorax nycticorax*	275	1	0.22
5 Bittern *Botaurus stellaris*	900	1	0.22
6 Pintail *Anas acuta*	700	1	0.22
7 Common Teal *A. crecca*	300	1	0.22
8 Blackwinged Kite *Elanus caeruleus*	270	6	1.30
9 Pariah Kite *Milvus migrans govinda*	680	115	25.00
10 Blackeared Kite *M. (m.) lineatus*	750	2	0.43
11 Brahminy Kite *Haliastur indus*	600	12	2.61
12 Sparrow Hawk *Accipiter nisus*	200	1	0.22
13 Longbilled Vulture *Gyps indicus*	5000	2	0.43
14 Whitebacked vulture *G. bengalensis*	4500	82	17.83
15 Scavenger Vulture *Neophron percnopterus*	2000	3	0.65
16 Montagu's Harrier *Circus pygargus*	250	2	0.43
17 Pale Harrier *C. macrourus*	300	1	0.22
18 Marsh Harrier *C. aeruginosus*	400	1	0.22
19 Short-toed Eagle *Circaetus gallicus*	1500+	1	0.22
20 Readheaded Merlin *Falco chicquera*	225	1	0.22
21 Kestrel *Falco tinnunculus*	125-150	3	0.65
22 Black Partridge *Francolinus francolinus*	400	1	0.22
23 Rain Quail *Coturnix coromandelica*	75	2	0.43
24 Painted Bush Quail *Perdicula erythrorhyncha*	80	1	0.22
25 Indian Peafowl *Pavo cristata*	4000	1	0.22
26 Demoiselle Crane *Anthropoides virgo*	2500	1	0.22
27 Painted Snipe *Rostratula bengalensis*	125	1	0.22
28 Blackwinged Stilt *Himantopus himantopus*	170	1	0.22
29 Stone Curlew *Burhinus oedicnemus*	380	9	1.96
30 Small Indian Pratincole *Glareola lactea*	40	2	0.43
31 Large Indian Pratincole *G. pratincola*	125	1	0.22
32 Redwattled Lapwing *Vanellus indicus*	190	15	3.26
33 Yellowwattled Lapwing *V. malabaricus*	110	7	1.52
34 Eastern Golden Plover *Pluvialis dominica*	103	1	0.22
35 Gull *Larus* sp	116-405	2	0.43
36 Sooty Tern *Sterna fuscata*	200	1	0.22
Unidentified egret		1	0.22
Unidentified raptor		1	0.22
Unidentified vultures *Gyps* sp		18	3.91
Unidentified harrier *Circus* sp		2	0.43

TABLE 1. (Contd.)

37 Indian Sandgrouse *Pterocles exustus*	250	4	0.87
38 Yellowlegged Green Pigeon *Treron phoenicoptera*	250	2	0.43
39 Blue Rock Pigeon *Columba livia*	300	30	6.52
40 Ring Dove *Streptopelia decaocto*	130	7	1.52
41 Red Turtle Dove *S. tranquebarica*	90	1	0.22
42 Spotted Dove *S. chinensis*	125	12	2.61
43 Little Brown Dove *S. senegalensis*	80	3	0.65
44 Roseringed Parakeet *Psittacula krameri*	120	4	0.87
45 Koel *Eudynamys scolopacea*	160	1	0.22
46 Spotted Owlet *Athene brama*	120	1	0.22
47 Great Horned Owl *Bubo bubo*	1100	1	0.22
48 Barn Owl *Tyto alba*	300	2	0.43
49 European Nightjar *Caprimulgus europaeus*	75-100	1	0.22
50 Indian Little Nightjar *C. asiaticus*	46	1	0.22
51 Swiftlet *Collocalia* sp.	15	2	0.43
52 House Swift *Apus affinis*	20	21	4.57
53 Palm Swift *Cypsiurus parvus*	18	5	1.39
54 Bluetailed Bee-eater *Merops philippinus*	30-40	1	0.22
55 Kashmir Roller *Coracias garrulus*	170	2	0.43
56 Indian Roller *C. benghalensis*	170	3	0.65
57 Short-toed Lark *Calandrella cinerea*	20	2	0.43
58 Crested Lark *Galerida cristata*	20	1	0.22
59 Common Swallow *Hirundo rustica*	18	2	0.43
60 Indian Cliff Swallow *H. fluvicola*	10	1	0.22
61 Redrumped Swallow *H. daurica*	18	4	0.87
62 Rufousbacked Shrike *Lanius schach*	25	1	0.22
63 Common Myna *Acridotheres tristis*	110	6	1.30
64 Pied Myna *Sturnus contra*	75	1	0.22
65 Starling *Sturnus vulgaris*	60-80	1	0.22
66 House Crow *Corvus splendens*	300	4	0.87
67 Jungle Crow *C. macrorhynchos*	500	2	0.43
68 Bluethroated Flycatcher *Muscicapa rubeculoides*	15	1	0.22
69 Longtailed Warbler *Prinia* sp.	5-8	1	0.22
70 House Sparrow *Passer domesticus*	25	1	0.22
(B) Bats			
71 Indian Pigmy Pipistrelle *Pipistrellus mimus*	20	2	0.43
72 Tomb Bat *Taphozous* sp.	25	1	0.22
73 Flying Fox *Pteropus giganteus*	600	2	0.43
Unidentified dove *Streptopelia* sp.		1	0.22
Unidentified nightjar *Caprimulgus* sp.		1	0.22
Unidentified swifts and swallows		5	1.09
Unidentified mynas		2	0.43

FIGURE 1. Activity-wise break up of problem birds in India during 1966-91

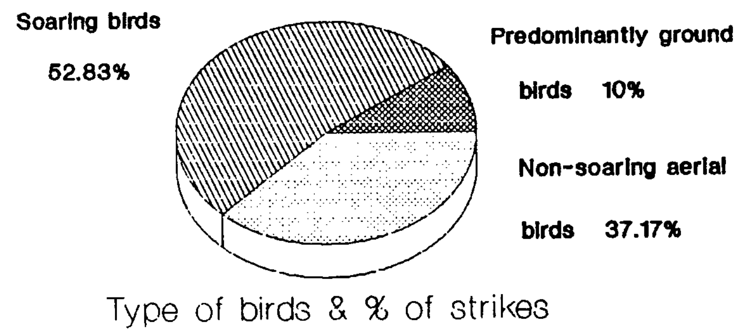
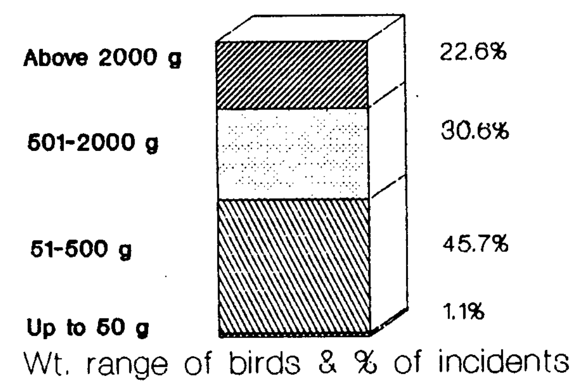


FIGURE 2. Weight-wise distribution of problem birds in India during 1966-91



more often by aircraft included the pigeons (6.95%), doves (5.27%), lapwings (4.78%), stone curlew (1.96%), owls (0.87%)as well as swifts and swallows (8.91%) as shown in TABLE 1.

An activity-wise break up of the problem birds involved in 460 incidents showed soaring birds such as vultures, kites and harriers have caused more number of strikes (52.83%) than nonsoaring aerial birds (31.17%) such as pigeons, doves, crows, swifts, swallows, mynas, starlings, bee-eaters, and flycatchers and predominantly ground birds (10%) such as partridges, quails, peafowl, lapwings and stone curlew (FIGURE 1).

A weight-wise analysis of birds and bats involved in 460 aircraft strike incidents revealed that more than half (52.8%) of the problem species weighed from half a kg to five kg in which are included the vultures, kites, the Short-toed eagle, the Great Horned Owl, peafowl, the Bittern, the Pintail, cranes, gulls, the jungle crow and the Flying fox (TABLE 1 & FIGURE 2). Birds weighing less than 50 g caused only 1.1% of the strikes, whereas those weighing between 50 and 500 g were responsible for 45.7%.

Some of the difficulties faced by the BNHS in identifying bird remains are,

1. In many cases the flight safety officials do not send bird remains or identifiable material. At times the feather remains lack downy barbs which are necessary for microscopic examination and identification of bird species.

2. Airline officials especially those from foreign airlines do not send data and bird remains to experts in the country where the incident occurred.

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REFERENCES

BROM, T.G. (1980): Microscopic identification of feather remains after collisions between birds and aircraft. 1-89 (mimeographed report). Amsterdam.

BROM, T.G. (1991): The diagnostic and phylogenetic significance of feather structures. Ph. D. Thesis. University of Amsterdam.

BROM, T.G. & BUURMA, L.S. (1974): The quality of identification: a microscopic key to the determination of feather remains. 14 Meeting BSCE, the Hague, WP 19 (1-6).

GRUBH, R.B. (1989): Ecological Study of Bird Hazard at Indian Aerodromes Phase 2 Final Report (1982-88) Part One: Summary of the Findings and Recommendations. Bombay Natural History Society.

LAYBOURNE, R.C. (1984): Identification of feather remains from bird aircraft incidents by the microstructure of the downy part of the feather in *Proc.* 17 Meeting of BSCE (Rome): 282-286.

ROSALIND, L. & GRUBH, R.B. (1987): Microscopic identification of feathers aiding bird hazard prevention programme in India. *Journ. Bombay nat. Hist. Soc.* 84(2): 429-431.

SATHEESAN, S.M. (1990): Ecology and behaviour of the Pariah Kite *Milvus migrans govinda* Sykes as a problem bird at some Indian aerodromes. Ph. D. Thesis. University of Bombay.

SATHEESAN, S.M., GRUBH, R.B. & PIMENTO, R.J. (IN PRESS): An updated list of birds and bat species involved in collision with aircraft in India. *Journ. Bombay nat. Hist. Soc.* Bombay.

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JERUSALEM, 22-27 MARCH 1992

MIGRATORY-BIRD STRIKES TO AIRCRAFT IN INDIA

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ABSTRACT

India, unlike Israel which has a high concentration of migratory birds because of its geographical location between Asia and Africa forming an isthmus between the two continents, serves merely as a destination or land route for several species of migratory birds. From bird-strike remains 13 migratory bird species were identified during the period 1966 and 1991 in India. The plant and animal food available to birds and the open, vast and tranquil aerodrome areas which provide the safety needed by the birds while feeding, resting and nesting, are irresistible attractions. By our national effort supported by the Aeronautics R & D Board of India, the Bombay Natural History Society and airport authorities the aerodrome environments are being made ecologically unattractive to birds and this is reducing aircraft strikes due to birds including migratory ones within aerodrome areas at ground level and lower altitudes.

INTRODUCTION

The Bombay Natural History Society which has gathered over the years a wealth of information on migratory birds through bird-ringing, studied the ecological aspects of bird hazards to aircraft in India with the sponsorship of Aeronautics R & D Board from 1980 onwards. The data gathered on bird-strike incidents by the BNHS also includes those on migratory birds. These are documented below.

MATERIALS AND METHODS

Between 1966 and 1991 the BNHS had received 460 identifiable bird remains along with bird-strike data. The samples were examined macroscopically comparing with bird skins from the BNHS Collections and microscopically comparing internal structure of feathers from known birds through standard techniques. Till the beginning of 1990, 67 species of birds were identified from 360 bird aircraft strike remains (Satheesan, Grubh & Pimento, IN PRESS). By the end of 1991 the number of species of birds identified rose to 70. Between 1980 and 1989 the BNHS Bird Hazard Study Team conducted field research in 22 aerodromes in India and obtained first hand knowledge of potential problem birds in and around these aerodromes.

RESULTS AND DISCUSSIONS

Of the 70 species of birds identified from bird remains, only 13 species were found to be migratory in nature. All the 20 strikes on aircraft by migratory birds (TABLE 1) occurred between late August and early April. Majority of these birds are winter visitors arriving the sub-continent by September/October and leaving India by March/April. The European nightjar is a summer visitor to India. The Kashmir roller migrates to peninsular India in spring and returns in autumn (Ali & Ripley 1983). Demoiselle cranes which are winter visitors, are known to have regular autumn migration over Kohar in NW Pakistan (Ali & Ripley 1983). One Demoiselle Crane which hit an aircraft in the month of August was presumably in autumn migration or an early arrival for wintering in the sub-continent.

An analysis of 16 migratory-bird strikes according to the flight phases of aircraft revealed that 43.75% occurred within the aerodrome area while the aircraft was taxiing or on its

take-off run or landing roll where as the rest occurred outside in approach and level flights (FIGURE 1). Bittern, harriers, gull and sooty tern struck aircraft inside the aerodrome while ducks, demoiselle crane, golden plover, gull, common swallow, european nightjar and kashmir rollers did so outside aerodrome.

An hourly distribution of 20 bird strikes involving migratory birds showed that most of these incidents (70%) had occurred during day-light hours (FIGURE 2). Of all the incidents only two hits by ducks and one by Kashmir roller which occurred at night time appear to be positively during migratory flight they are otherwise diurnal birds. Cranes, Golden plover, gulls and swallows encountered by aircraft outside aerodrome could be in migration or in foraging flights. But birds hit within aerodrome area might have visited the locality for food or shelter.

Migratory birds have been recorded to have struck aircraft in India upto an altitude of 2424 m (Satheesan, 1990). Most of these incidents (94.12%) had occurred at and below 400 m. Out of 16 incidents where the altitude of strike was known, 56.25% occurred outside the aerodrome area.

Migratory-bird strikes have caused at least six precautionary landings other than slight to serious damage to aircraft engines (five occasions), wing (thrice), landing gear and lights (four times), nose (four times), incident probe in nose area (once), windshield (twice) and fuselage (once). The heaviest migratory bird species recorded to have struck aircraft in India was Demoiselle crane weighing about 2.5 kg. (TABLE 2). Some of the other heavier species were Bittern (c. 900 g) and ducks (300-700 g).

Methods suggested (Grubh 1989, Satheesan 1990) to reduce bird hazards at Indian aerodromes by removing all ecological attractions to birds like food and shelter, resting and roosting facility are also applicable to migratory birds which frequent the airfields.

ACKNOWLEDGEMENTS

This paper is prepared from the data collected as a function of the BNHS Bird Hazard Research Cell funded since 1980 by the aeronautics R & D Board, Ministry of Defence, Government of India, through its Operational Problems Panel.

TABLE 1. Migratory-birds in collision with aircraft in India between 1966 and 1991

	Species	Locality	Migratory season	Date of incident	Hours of activity	Time of incident
1.	Bittern *Botaurus stellaris*	c.31.26N 75.43E	Autumn-Spring	23-04-86	Crepuscular & nocturnal	2130 hrs.
2.	Common teal *Anas crecca*	c.30.55N 75.54E	Winter	04-03-87	Day & night	2012-2053 hrs.
	Common teal	c.30.55N 75.54E	-do-	22-10-90	Day & night	2023 hrs.
3.	Pin tail *Anas acuta*	c.33.50N 75.00E	-do-	06-04-87	Day & night	0835-0950 hrs.
4.	Montagu's harrier *Circus pygargus*	28.35N 77.05E	Winter	21-09-87	Day	Not known
	Montagu's harrier	c.17.15N 78.20E	Winter	24-11-87	Day	0945 hrs.
5.	Marsh harrier *Circus aeruginosus*	12.52N 74.53E	Winter	08-11-87	Day	0710 hrs.
6.	Pale harrier *Circus macrourus*	c.17.15N 78.20E	Winter	13-02-89	Day	1700 hrs.
	Harrier	22.28N 70.04E	Winter	15-10-90	Day	0800 hrs.
	Harrier	c.26.42N 88.25E	Winter	06-11-90	Day	0900 hrs.
7.	Demoiselle crane *Anthropoides virgo*	17.54N 77.33E	Winter	29-08-84	Day	1547 hrs.
	Crane Gruidae	26.17N 73.02E	Winter	07-09-89	Day	1040 hrs.
8.	Eastern Golden plover *Pluvialis dominica*	26.38N 92.48E	Winter	28-01-86	Day & night	1535 hrs.
9.	Gull *Larus* sp.	15.05N 74.35E		26-02-87	Day	0820 hrs.
	Gull *Larus* sp.	17.42N 83.18E	-do-	20-08-90	Day	1328 hrs
10.	Sooty tern *Sterna fuscata*	18.32N 73.52E	Not known	24-01-83	Day	2030 hrs

TABLE 1. (Contd.)

11.	Common swallow *Hirundo rustica*	26.38N 92.48E	Winter	27-10-88	Day	1410 hrs
	Common swallow	26.38N 92.48E	Winter	15-03-89	Day	1230 hrs
12.	European nightjar *Caprimulgus europaeus*	23.16N 69.40E	Summer	26-09-87	Night & crepuscular	2000 hrs.
13.	Kashmir roller *Coracias garrulus*	15.05N 74.35E	Autumn	10-10-87	Day	2100 hrs.
	Kashmir roller	26.45N 83.24E	Autumn	23-08-91	Day	0900 hrs.

TABLE 2. Migratory-bird strikes in India between 1966 and 1991

Bird groups	No. of species	wt. in g	No. of strikes	Locality	Effect on flight	Damage to aircraft
1. Bittern	1	900	1	NW	Nil	Not known
2. Ducks	2	300-700	3	NW	Pl	Engine (twice), wing (twice) Nose & Landing gear
3. Harriers	3	250-400	6	N, NE, W S & SE (twice)	Nil	Landing gear, Engine, Ventral fin, Cooling duct
4. Crane	1	2500	2	NW & S	Pl	Windshield, Fuselage & wing
5. Plovers	1	103	1	SE	Pl	Not known
6. Gulls	1	116-405	2	SW & E	Pl	Wind shield, Nose cone & Landing lights (twice)
7. Tern	1	200	1	W	Nil	Not known
8. Nightjar	1	75- 100	1	W	Nil	Engine & Nose cone
9. Roller	1	170	1	SW & N	Pl	Engine & Nose
10. Swallows	1	18	2	NE (twice)	Nil	Nil

Pl - Precautionary landing Ab. T/O - Aborted Take-Off

FIGURE 1. Migratory-bird hits in India at various flight phases of aircraft

n = 16

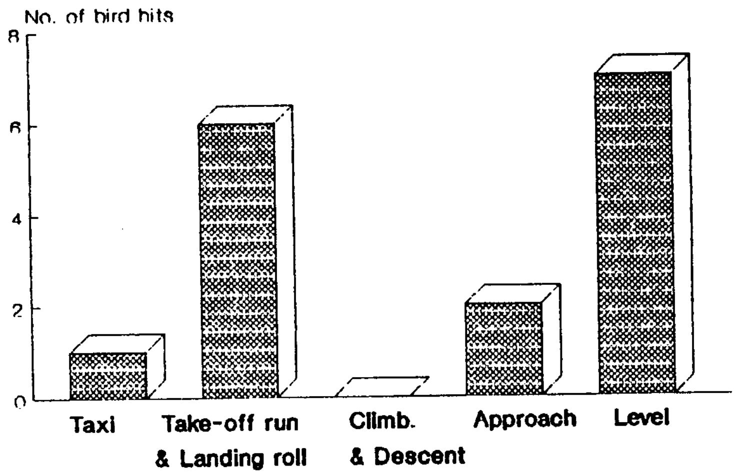
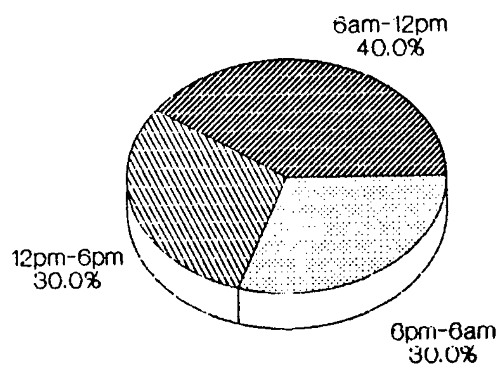


FIGURE 2. Migratory-bird hits in India at day and night time during 1966-91

n =20



REFERENCES

ALI, S. & RIPLEY, S.D. (1983): Handbook of the Birds of India and Pakistan, Compact Edition. Oxford University Press, Bombay

ALI, S. & GRUBH, R.B. (1984): An Ecological Study of Bird Hazards at Indian Aerodromes.Phase 2 First Annual Report. Bombay Natural History Society, Bombay

GRUBH, R.B. (1989): Ecological Study of Bird Hazard at Indian Aerodromes Phase 2 Final Report (1982-88) Part One: Summary of the Findings and Recommendations

SATHEESAN, S.M. (1990): Ecology and behaviour of the Pariah Kite *Milvus migrans govinda* Sykes as a problem bird at some Indian aerodromes. Ph. D. Thesis. University of Bombay. Bombay

SATHEESAN, S.M. (1990): Bird-aircraft collision at an altitude of 2424 m over the sea. *Journ. Bombay nat. Hist. Soc.* 87(1): 145-146

SATHEESAN, S.M., GRUBH, R.B. & PIMENTO, R.J. (IN PRESS): An updated list of birds and bat species involved in collision with aircraft in India. *Journ. Bombay nat. Hist. Soc.* Bombay.

SATHEESAN, S.M. (IN PRESS): Extension of range of the Kashmir Roller (Blue Jay) to Gorakhpur, Uttar Pradesh. *Journ. Bombay nat. Hist. Soc.* Bombay.

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BIRD STRIKE HAZARDS TO HELICOPTERS

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ABSTRACT

Within the European Rotorcraft Forum collisions between helicopters and birds have recently been discussed in relation to joint european airworthiness requirements (JAR 27 and JAR 29). This has trigerred the RNLAF to analyse her Alouette-III and Bolkow-105 bird strike statistics with respect of flying hours and the weight of the birds concerned. The surprisingly high ratio's, compared to civil statistics used so far, stimulated to explore the newly formed European Military Bird Strike Database and to ask for experiences of NATO partners. An over-all rate of 5.4 bird strikes per 10.000 flying hours for 10 helicopter types (N = 1471) was found, including 7 - 29 % damage cases. The chance of serious accidents is estimated to be higher than 10^{-6}. Different helicopter types showed persistently differing figures. Explanations for these differences are put into question. The empirical quantitative data may affect the decision making within the Helicopter Airworthiness Study Group.

1. INTRODUCTION

Catastrophic helicopter accidents due to collisions with birds are generally not assumed to occur, as they have not been described sofar (although at least two cases have been disputed). Nevertheless, helicopter bird encounters are numerous and military statistics show a fairly high frequency of bird strikes with minor damage, mostly broken transparancies but sometimes also rotor blade deformation and damage to air intakes, causing riskful situations.

Recent discussions on the joint european airworthiness requirements (JAR 27 and JAR 29) with respect to helicopter bird impact resistance have triggered us to explore the RNLAF database for collisions between Alouette III and Bolkow 105 helicopters and birds. Subsequently, we also checked the recently created European Database of Military Bird Strikes (ref 1) and asked our British and German colleages additional information.

The aim of this report is to supply quantitative data on bird strike rates per bird weight class as a reference for the Helicopter Airworthiness Study Group (HASG). A recent meeting of the European Rotorcraft Forum has clarified the need for such data when adopting certification standards for future helicopters. Also the coordination with US counterparts is at stake. Helicopter bird strike rates have never been reported in this detail sofar.

2. BIRD STRIKE NUMBERS: AVAILABILITY AND RELIABILITY

Bird strike statistics can be unreliable. Firstly, there may be bias due to insufficient and inconsistent reporting, and secondly, there is the statistical effect of small numbers. Reliable insight can be improved by mandatory documentation and careful analysis over many years. Alternatively, the bird strike experience of a big helicopter fleet could be monitored for a short period. But then the lumping of collisions of different helicopter types with birds in different geographical situations may hamper the analysis.

2.1 RNLAF data.

The Dutch helicopter fleet is small but uniform as it consists of only two types and has been flown over the last decade in a stable pattern with respect of flying hours and area of operation. In fig. 1 the geographical distribution of the Dutch heli bird strikes over nine years are plotted. The patterns appears to be surprisingly even, not reflecting certain bird concentration areas. In fact, the map perfectly indicates the area of helicopter operations and the 'density of helicopter flying'. The two 'multi-strike dots' represent Soesterberg AFB and Deelen AFB where the majority of flights started and ended and local (training) flights were performed.

Fig. 2 shows the bird strike rate per 10.000 flying hours from 1977 up to and including 1990 for both helicopter types. The yearly number of flying hours fluctuated between 13.156 and 17.316 for the Alouette III and between 5.916 and 8.443 for the Bolkow 105. Given the fairly low number of 167 bird strikes over those fourteen years the ratio's are remarkedly stable. We could neither find a correlation in the fluctuations between both types nor a significant relation with indices for the bird population. So, we assume the fluctuations to reflect statistical noise. Also no long term trend can be seen.

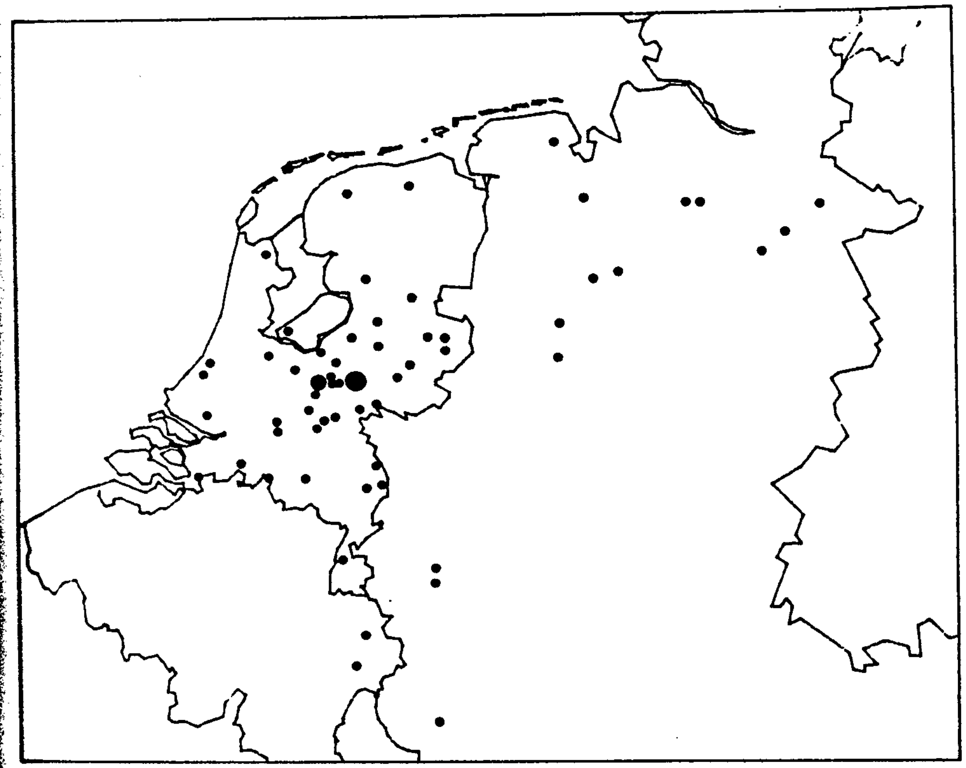


Figure 1. Geographical distribution of bird strikes with RNLAF helicopters 1982 - 1990 (N = 91, location unknown: 16).

Legend: : 1 strike
2-10 strikes
>10 strikes

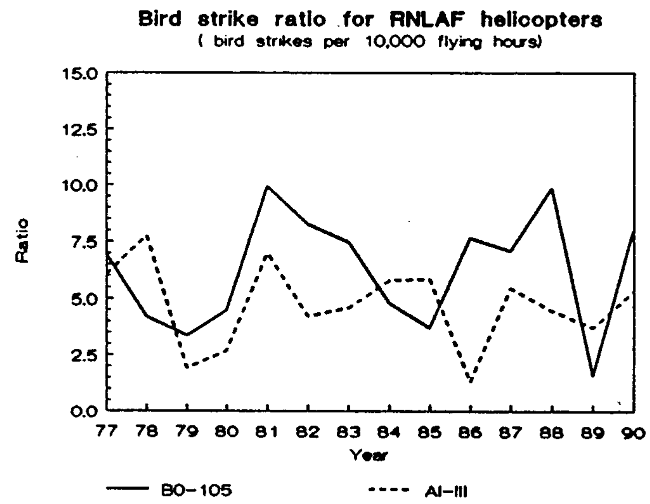


Figure 2.

The spatial and temporal patterns indicate a good reporting standard within the RNLAF as it was also found in earlier jet fighter analyses (refs 2 and 3). So we conclude that the data set is suitable for the calculation of a reliable average ratio for the total number of bird strikes as well as the strikes resulting in any damage to the helicopters: table 1.

	Al-III	Bo-105
Total flying hours 1977 - 1990	219,937	100,494
Overall ratio per 10.000 flight hours	4.73	6.27
Ratio for damage cases only	1.23	0.70

Table 1. Bird strike ratios for RNLAF helicopters during the period 1977 - 1990

Having found a ratio more than five times higher than the one disputed in the HASG (ref 4) and the high proportions of non-damaging strikes, we felt obliged to compare the RNLAF data with the much larger but less documented data sets of RAF and GAF. A check with respect of damage percentages could indicate the comparability and thus the possibility to combine the scarce data on bird weights.

2.2 European database of military bird strikes.

So far, only the contributions of GAF, RAF and RNLAF to the database met the criterion of at least 10 bird strikes per helicopter type. These contributions are very substantial and listed in table 2 together with some characteristics of the helicopter types concerned.

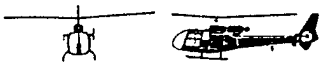
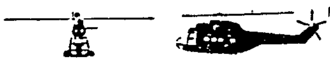
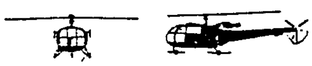
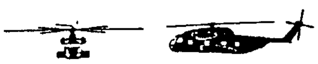
The column 'Perc. Damage' shows that all heli's belong either to a group 7 - 9 % or 20 - 29 %, irrespective of the air force. Furthermore, the Bolkow's and Alouette's of GAF and RNLAF respectively showed nearly the same proportions of damage. The general conclusion must be that the reporting standard of the three air forces is very similar.

The comparability of reporting also gives confidence to rely upon all three air forces with respect of the calculation of bird strike ratio's per 10.000 flying hours (last column in table 2). A prove of the comparability can be seen in the ratio for the Bö-105: GAF 7.1 and RNLAF 6.3. Also the two Alouette types come very close. The over-all ratio is 5.4 for all military helicopter-bird strikes with and without damage.

3. RATES ABOVE BIRD WEIGHT THRESHOLDS

The German and Dutch data proved not only to be very comparable, but also to come from a highly overlapping area of operations. Therefore, we combined the data and looked at the bird identification results in order to assess the proportion of different bird weight classes. During the last decade the RNLAF prescribes a rigid collecting of bird remains (even mere blood smears) and led these be identified professionally, if necessary by the microscopic method (ref 5). Although the percentage of identified birds was much lower in the GAF data (46.6 %, n=994) than in the RNLAF data (84.1 %, n=107) we concluded that the identifications nevertheless reasonably can represent the real bird weight distribution. This is shown in figure 3A where we plotted the damage proportion against the bird weight classes (middle values). The data come from table 3. In the figure the arrow gives the damage percentage for those bird strikes of which no bird information was available. The GAF and the RNLAF contributed equally to this low figure (both 5.9%). It is obvious that the non-identified birds (mainly from the German data set) all must have been small birds belonging to the lowest bird weight class. So, we added the 'unknowns' to the bird weight category '<51 grams' in order to calculate the cumulative proportion of all bird strikes over minimum bird weights (fig 3B). The last column of table 3 shows the percentage of all bird strikes above and including a certain bird weight class. Fig 3A and 3B were combined into a curve representing the cumulative proportion of all strikes with damage per minimum bird weight: fig 3C.

With fig 3B and 3C we now can calculate the chance of hitting a bird over a certain weight per flying hour, and also the chance that there will be damage. On the basis of 5.4 per 10.000 flying hours as the over-all helicopter bird strike rate over the German Plains we get fig 4. From the curves we conclude that a damaging bird strike due to a bird over 2-pound and over 4-pound will occur 4 - 5 and 2 - 3 times per one million flying hours respectively.

	Table 2 Helicopter	Characteristics			GAF		RNLAF		RAF		Total	
		Front. area	Perc. transp.	Rotor diam.	Tot.	Dam.	Tot.	Dam.	Tot.	Dam.	Perc. Damage	Ratio
	Gazelle	2.2	78	10.5	-	-	-	-	21	5	24	1.8
	Seaking	7.3	24	18.9	13	6	-	-	43	10	29	5.2
	Puma	4.1	45	15.0	-	-	-	-	168	44	26	11.4
	Wessex	8.1	21	17.1	-	-	-	-	78	20	26	2.8
	Al-2	2.5	75	10.0	161	33	-	-	-	-	21	4.0
	Al-3	3.9	74	11.0	-	-	104	27	-	-	26	4.7
	Bö-105	4.6	73	9.8	378	31	63	7	-	-	9	6,7
	CH-53	10.5	23	22	112	22	-	-	-	-	20	7.0
	Sealynx	5.0	43	12.8	12	1	-	-	-	-	8	-
	Bell UH	3.6	68	14.6	318	21	-	-	-	-	7	5.3
	Total	-	-	-	994	114	167	34	310	79	15	
	Period				1979-1989		1977-1990		1981-1990			

Air Force	GAF ('79-'89)						RNLAF ('82-'90)				Grandtotal				
Helicopter	Al-2		Bö-105		Other		Al-3		Bö-105		Total			Perc.	Cum. %
Damage	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	Total		
Bird weight class (grams)															
< 51	43	6	128	12	134	8	17	4	22	2	344	32	376	34.1	100.0
51 - 100	2	1	9	1	14	2	7	0	2	0	34	4	38	3,5	22.3
101 - 200	1	0	2	0	1	2	1	0	0	0	5	1	6	0.5	18.8
201 - 400	17	11	15	9	33	13	14	7	4	2	83	42	125	11.4	18.3
401 - 800	0	2	7	3	19	5	1	2	1	1	28	13	41	3.7	6.9
801 -1600	1	2	6	1	12	8	1	2	0	0	20	13	33	3.0	3.2
> 199	0	0	0	0	1	1	0	0	0	0	1	1	2	0.2	0.2
Unknown	64	11	180	5	191	12	7	1	9	0	451	29	480	43.6	-
Total	128	33	347	31	405	50	48	16	38	5	966	135	1101	100.0	
Grand total	161		378		455		64		43						

Table 3

Bird weight and damage proportion for all GAF and RNLAF helicopter strikes

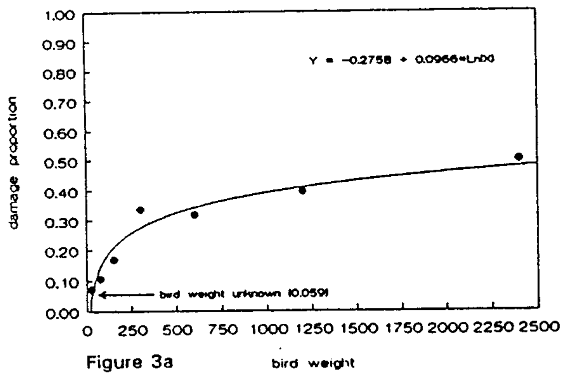


Figure 3a bird weight

Cumulative distribution of bird strikes over minimum bird weights (GAF + RNLAF)

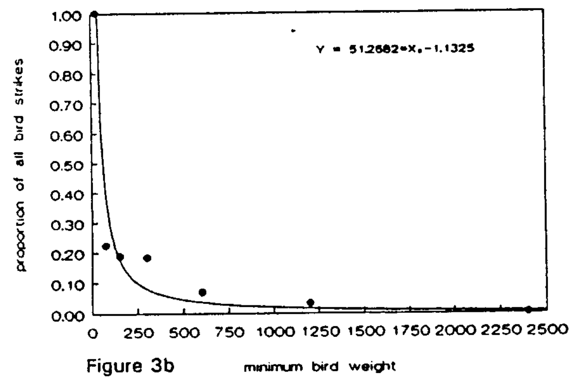


Figure 3b minimum bird weight

Relative chance to suffer any damage per bird weight (a and b combined)

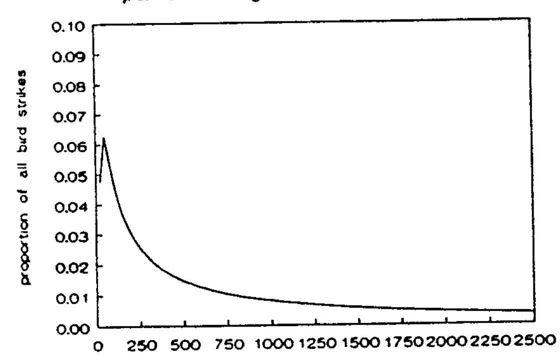


Figure 3c minimum bird weight

Strike frequency of helicopters with birds above a certain weight

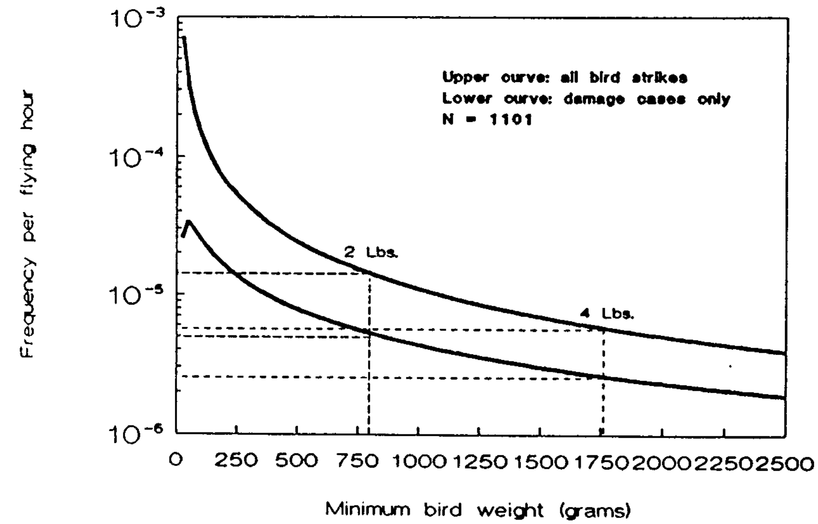


Figure 4.

4. DISCUSSION

We refrain of drawing further conclusions with respect of the type of risk connected to the quantifications given above. Of course, much depends on the design of critical parts of the helicopter which constitute only small proportions of the frontal surface. This should be discussed with helicopter designers on the basis of detailed impact resistence figures and a further analysis of the database with respect of peculiarities concerning damage.

There will be risk reduction because of the use of visors, the presence of a co-pilot and the possibilities of making emergency landings. This must have reduced the occurrence of serious accidents. But it also may have masked the initial bird strike in a chain of mishaps leading to a helicopter crash, as has been pointed out in jet fighter bird strike analysis (ref 3).

The military way of operating could have some influence on bird strike frequency. We did not collect data on the flight envelopes of the civil equivalents of our helicopter types. In stead we give in fig 5 and 6 some statistics from the Alouette II/III and ... show bird strikes with respect of helicopter speed and flying altitude. They show a result that seems reasonably comparable with many civil operations or give indications how to correct for deviations.

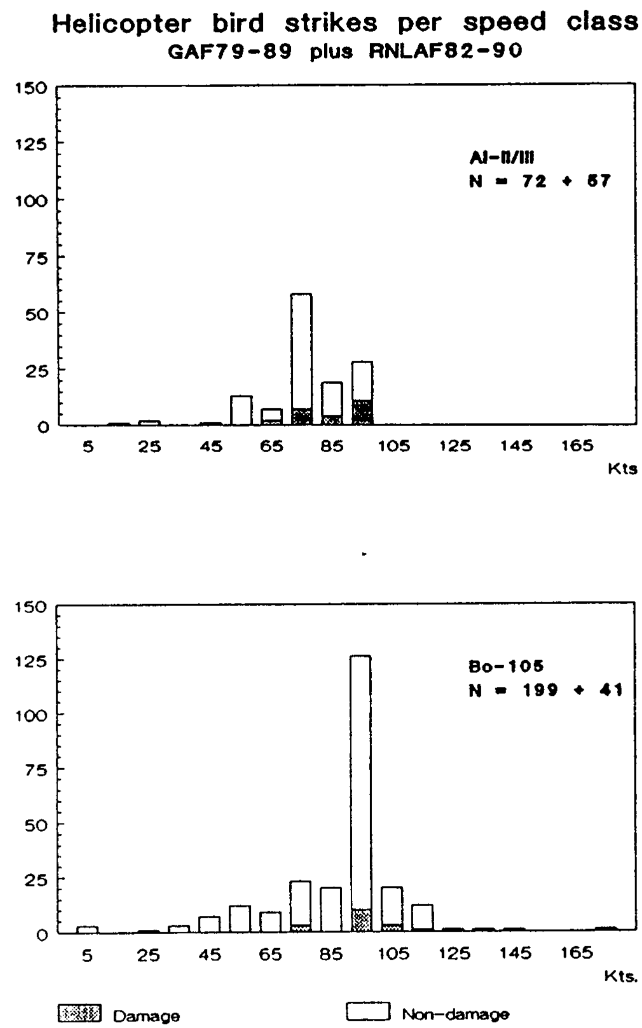


Figure 5

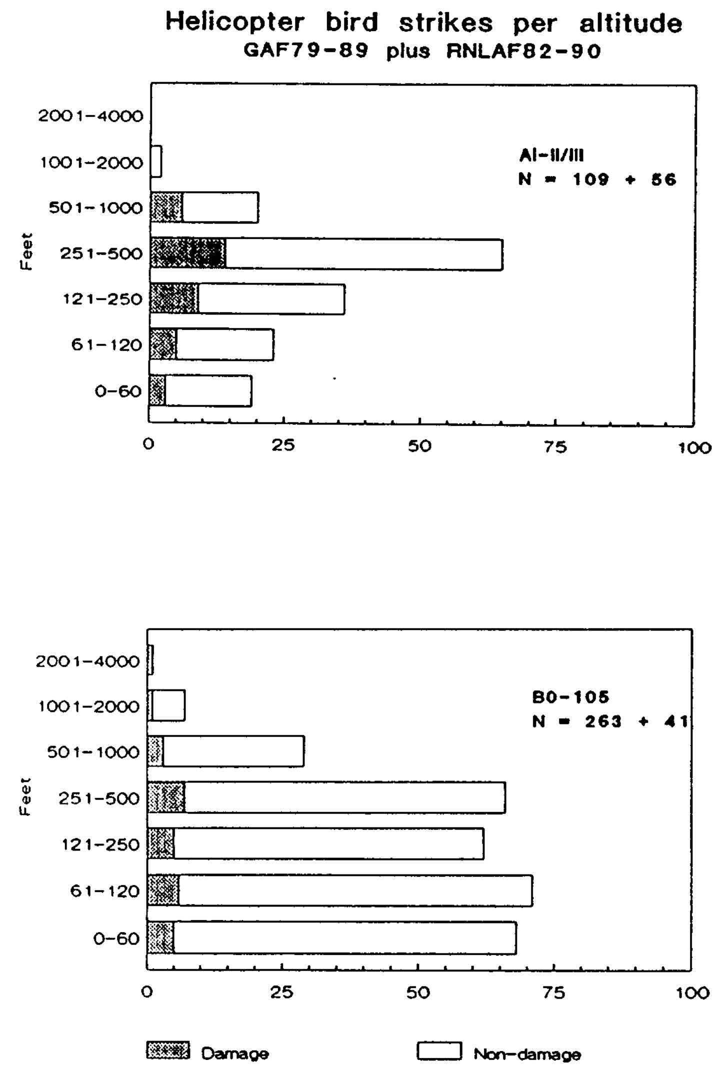


Figure 6

The example of the Alouettes and Bolkows also illustrates specific differences from helicopter to helicopter, which could be explained by design and application of airworthiness criteria. The Bo-105 is flown at lower altitudes (encountering more birds) at somewhat higher speeds (giving pilot and the birds smaller chances to perform evasive actions) than the Al-II/III. The bird strike rate is indeed somewhat (but not much) higher. However, the damage percentage is more than 2 times lower.

We feel that the empirical quantitative ratio's, as condensed in fig 4, offer a firm basis for extrapolations assessing the risks connected to design criteria and flight envelopes of future helicopters.

5. ACKNOWLEDGEMENTS

We thank SqLdr R.C. McLoud (RAF), Dr J. Becker (GAF), Mr J. Thorpe (CAA, UK) and Ir H.J.G.C. Vodegel (Nat. Aerospace Lab, Amsterdam, NL) for data and comments.

6. REFERENCES

1. Dekker, A & L.S.Buurma (1990), Towards a european database of military bird strikes. Proceedings 20th Meeting Bird Strike Committee Europe, pp. 105-128, Working Paper 14, Helsinki.

2. Buurma, L.S. (1983), Increasing bird strike rates and improved bird strike analysis of the RNLAF. Proc. 14th Conf. on Aerospace Transparant Materials and Enclosures. Scottsdale, Arizona, pp. 690-715 (report AFWAL-TR-83-4154).

3. Buurma, L.S. (1984), Key factors determining bird strike and risks. Int. J. of Aviation Safety Vol 2: 91-107.

4. James, D.O.N. (1991), JAR29: Rotorcraft bird impact. Internal Memo CAA.

5. Brom, T.G. (1986), Microscopic identification of feathers and feather fragments of Palearctic birds. Bijdr. Dierk. 56: 131-204.

THE EUROPEAN DATABASE OF MILITARY BIRD STRIKES FROM PROPOSAL TO REALITY

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ABSTRACT

The requirements a database of bird strikes will have to meet is depending on the kind of questions to be answered. One limiting factor often is the number of available data; very frequently the sample is too small to obtain statistically significant results. In order to overcome this problem the adoption of a joined European database of military bird strikes was promoted at the 20th meeting in Helsinki. Since the joined database will have to serve as the main source of information for many different questions, the set-up has been chosen as broad as possible. This paper describes the progress made so far. Standardization of the structure of the database and the conventions concerning the contents, proved to be extremely important. Both have been the subject of several discussions within the 'Bird Hazard at Low-level working group'. Once agreement was reached, emphasis was put on the introduction of a European Bird Strike Form. In conjunction with the completion of the form a computerprogram was developped enabling efficient handling of the data. Now computerized data storage is within reach, management and feeding of the joined database will be less time consuming and more potential users can be convinced to join the project. This leaves more time to the real purpose of the joined database: extracting information that is relevant to flight safety.

1. INTRODUCTION

Bird strike risks differ from situation from to situation. For instance, the chance that a bird strike will result in damage is much higher in en-route situations, while local bird strikes -due to the critical flightphase- have a higher chance to evolve into a major accident. Other examples are the difference in consequences of bird strikes with different types of aircraft; or the influence of the type of operation on the chance of encountering a bird (ref.1).
This means that in any analysis of bird strike data the proper set of data has to be selected. As a consequence, the number of available data often turns out to be insufficient for statistical sound conclusions.
By combining bird strike data from several Forces the problem of limited numbers can be eliminated.

Within the Air Forces Flight Safety Committee (Europe) (AFFSC(E)) it was decided to engage the RNLAF to undertake a pilotstudy on the feasability of a joined European Military Bird Strike Database using the 1988 data from a limited number of Forces. The results of this study were presented during the 20th BSCE meeting in Helsinki (ref.2). Despite the limited material it proved possible to extract new information from the database and to acquire better understanding into the bird strike problem.
A further conclusion was that standardization should not be considered impossible and would substantially improve the potential value of the database. A relatively slight improvement in reporting should be sufficient. It was stated that the way to realise this objective would be the adoption of a standardised Report Form. In order to obtain full cooperation from pilots in the proper and full reporting of all bird strikes, the concept of such a 'European Military Bird Strike Form' should be such that it is straight forward and easy to fill in. Furthermore, the Form should be organised in such a way that feeding the data in a computerfile leaves no opportunity for misinterpretation.

This paper deals with the progress made in the development and introduction of the 'European Military Bird Strike Form' and accompanying computerprogram. Also an inventory is given of contributions received so far.

2. THE EUROPEAN MILITARY BIRD STRIKE FORM

Before designing a Form, considerations have to be made as to what kind of information is to be collected. In other words, the structure of the database has to be defined. In the course of the pilotstudy it became clear that different Forces have different approaches to the problem of gathering information on birdstrikes. Combining the best ideas from all contributors was the obvious approach.

Once the items on which information is to be collected are established, decisions had to be made concerning the way in which this information should be be expressed: the conventions used for the contents of the database had to be defined.
Both **structure** and **conventions** of the database together formed the starting point in the development of the Form.

Handling the 1988 data in the pilot study learned that that most of the contributers report in their native language. This proved to be a complicating factor. We therefore took as a further criterium that the Form should be bilingual.

Finally we considered that a distinction can be made between those items which together form the **main** contribution and those items that contain **additional**, country specific information. The Form therefore had to consist of two parts. The front side containing the essential information, additional information was concentrated on the back side of the Form.

A draft Form was presented at the 109th AFFSC(E) meeting (4-7 september 1990, London). It was decided that the Form need not to be bilingual and that english should be language used on the Form. Details on the contents of the Form were left for discussion within the BSCE Working Group 'Bird Hazards at Low Level' which was considered to act as a specialist group for AFFSC(E). This group meticulously examined the draft Form during their 6th meeting in The Hague (21-23 November 1990). Agreement was reached on both the contents and lay-out of the Form.

Reckognising the importance of standardization with respect to a joined European Database of Military Bird Strikes, the Military Agency for Standardization - Flight Safety working party (MAS/FS) on 31 januari 1991 decided to add the new standardized European Military Bird Strike Form as an annex to STANAG 3879FS.

A copy of the final version of the Form is given in appendix A.

3 THE TRANSFORMATION OF DATA FROM THE FORM INTO A COMPUTERFILE.

3.1. General concept.

Experience in analyses of the small, but very detailed RNLAF database was very helpfull in the considerations on how to realise computerised data handling. So, by taking into account the ultimate goal of extracting usefull information, the development of the database structure was realised simultaneously with the development of the Form.

The main problem in setting up a database is the contradictional fact that on the one hand there is a tendency to collect as much information as possible and leave a maximum degree of freedom in the description of the bird strike and the circumstances

under which it happened. On the other hand one does not want to strain the reporting system by asking too much. Furthermore, computerised data handling requires a very diciplined, persistent and consequent attitude towards the data. In fact, an optimum had to be found between a descriptive narrative and a keyword approach.
The Form leaves both options open; the tick-boxes narrow down the information to a limited number of entries while at the same time pilot remarks and comments can be entered as a narrative.

Different kinds of use of the database may each time require a different approach and specific software. To circumvent the inevitable compatibility problems, DBase 3+ is used as the format for datastorage. In this widespread database handling package data is stored in an easy reckognisable way, it also enables interactive manipulation of data. Last but not least, most other software packages do have import facilities for DBase format.

The Form purposeful offers the possibility to add pilot remarks and comments. For practical reasons these are stored in a separate datafile which is linked to the main file by the administration number. This means that a database for a specific Force and/or year does consist of two datafiles.

The program which facilitates computerised handling of the information from the Form should meet a minimum number of requirements. For several reasons we have decided not to use a DBase-application program. An executable file (.EXE) written in PASCAL offers a number of advantages such as speed and user-friendliness.

3.2. Structure and conventions used in the database.

Annex B describes in detail the structure and conventions used in the database. Conscientious comparison of the structure with the Form shows that the structure contains two fields that are not present on the Form. These auxiliary fields will be completed by the custodian of the database. They are meant to offer quick selection arguments that are frequently used in the analysis of bird strike data. The first of these fields is ACTYPE and should contain information on the aircraft category. The second auxiliary field (LOCENR) will contain information whether a bird strike occured en-route or not.

3.3. User aspects of the program.

This paper is not intended as a manual for the program. For details the users guide and manual has to be consulted. Here, only the main properties of the program are briefly discussed.

The general philosophy behind the set-up of the program is that it should be very user-friendly and that entries in the database should be limited to the conventions described in appendix B as far as possible.
The program is menu driven, it offers a limited number of options which are shown in the main menu.
There are a number of default settings which are used by the program (e.g. path and filename). The definition of these settings is one of the options the main menu offers. Other options include adding data, editing or deleting data and printing data. Please notice that the program does only offer the tools to these basis operations. Special

features needed when analysing data are not provided. The DBase format of the files enables interactive manipulation by DBase or easy import in any other software package.

The program defines several windows on the screen, these windows have separate functions and are consequently shown in the same colour. Since the full presentation of a record takes more space then is available on one screen the contents of a record is devided over 6 'pages' which coincide with reckognisable parts of the Form.
Apart from the main window, a status window is given in the left bottom corner and a window containing limited help is projected in the lower right hand corner of the screen (figure 1). The numbering of the various fields that are presented on the screen corresponds with the numbering on the European Military Bird Strike Form.

```
------------------------------ page 1 ------------------------------
01. Adm.number:                 RNLAF/TW9103    10. Flightphase:  LLE.
02. Incident date (DDMMYY):     260691          26 june 1991
03. Incident time:              12.15Z
04. Unit/Squadron:              313
05. Aircraft:                   F-16
06. Speed (kts):                400
07. Altitude (ft):              2000
08. Lat. Long. Coörd:           49.35N-10.20E
09. Geogr. Location:            20 NM EAST GIEBELSTAD
Mode: Edit data                 e.g.: 05.30Z        (Incident time, Zulu)
Path: E:\EURPROG\EURDATA\             15.00L-16.30 (Local time of mission)
File: VA91.DBF
```

Figure 1. General outline of the EURBIRD screen, showing several windows.

Throughout the program it is possible to ask for an extended help window by entering a < ? > in the first position of the field for which help is needed (figure 2).
Option windows are used for a number of fields to show the only admitted entries (figure 3). Some entries in the settings mode can be picked from a scroll window by putting the cursor-bar at the appropiate place using the arrow keys (figure 4). this

During the 7th meeting of the working group 'Bird Hazards at Low-Level' (Traben Trarbach, 9-11 september 1991) a first outline of the program was presented. The positive reactions with respect to this incomplete and imperfect first attempt were very encouraging and convinced us to go on along the taken course.

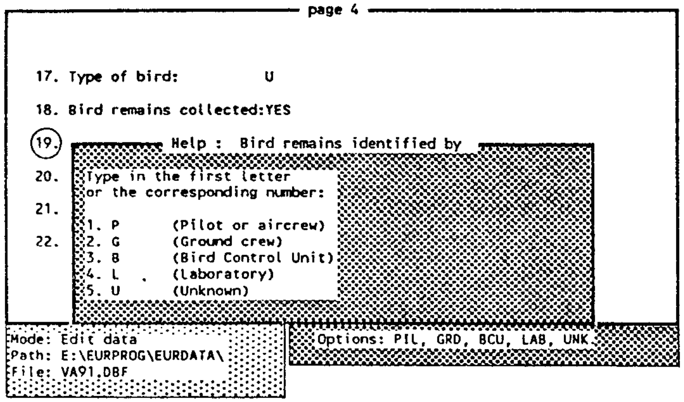

Figure 2. EURBIRD screen showing extended HELP function

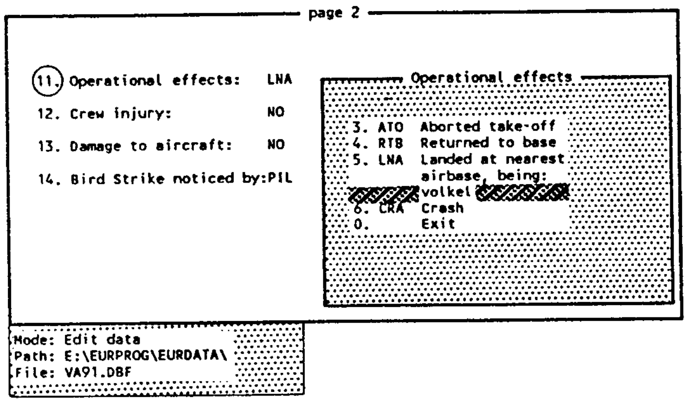

Figure 3. EURBIRD screen, showing an option window.

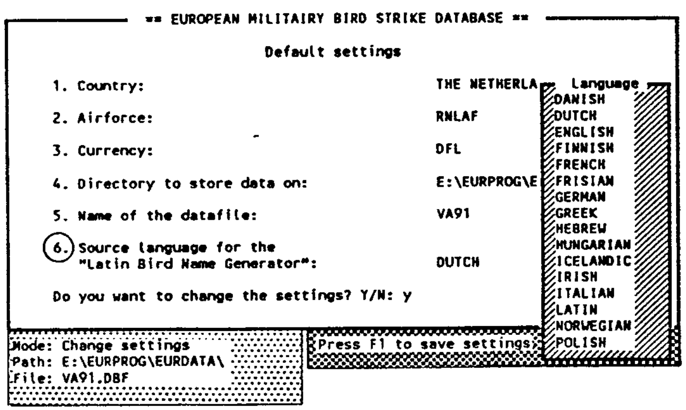

Figure 4. EURBIRD screen, showing the settings of default options.

3.4. The Latin Bird Name Generator

Entries in the field 'birdspecies' can be made in two ways. It is possible to use the 40 positions in this field for text that indicates the bird species involved. In fact, any text in any language is accepted. Entries of bird names in a range of different languages do limit the succesfull use of the database, therefore the use of the scientific Latin names should be promoted. To facilitate this, the program contains a 'Latin Bird Name Generator' which can be used when the bird involved is identified to the species level.

The Latin Bird Name Generator offers the possibility to use a scroll screen that shows - in alphabetical order- the bird names in a specified source language, next to these the appropiate Latin bird names are shown. By using PgUp/PgDn or Home/End and the arrow keys, a birdname can be selected. Pressing <ENTER> then activates the program and the Latin bird name is stored in the field birdspecies.

The Latin Bird Name Generator is also activated if the bird name is entered in the language which was specified in the settings. The program checks whether it 'knows' this specific bird species. If so, the latin name will be shown and stored in the data file. If the entered text in the field 'bird species' is not reckognised by the program as a bird name this text will be stored unchanged. This leaves the opportunity to enter any text in any language as a last option.

The information used by the Latin Bird Name generator is stored in the database BIRDS.DBF (in the program directory). The program and the database BIRDS.DBF can potentially serve 19 source languages, 17 of which are implemented. Due to problems with the Greek symbol set bird names in Greek are not (yet) available. Irish names are known to be published but not yet retrieved. For most of the 17 other languages the majority of the bird names are available. Scandinavian bird names were provided by P G. Bentz, bird names in other languages are mainly taken from H.I. Jorgensen (ref.3). Despite serious attempts to provide the Latin Bird Name Generator with correct and complete information, some names are missing and some are bound to be incorrect. In order to improve both the quality and the quantity of available bird names, completions and corrections are most welcome.

4 CONTRIBUTIONS TO THE DATABASE.

Since the analysis of 1988 bird strike data was presented (ref.2), the number of Forces of which data was received increased from five to twelve. All the contributions consisted of extractions of existing databases or incorporation in existing reporting systems. Merging all data into one European database thus means conversion of a multitude of data types into the agreed structure. An extra complicating factor is the fact that most contributions are not yet available as a computer file but only in a printed form. We are now in the process of transforming all existing data -as far as possible- to the new structure.

In figure 5 all the countries from which data are received are indicated. Details on the years for which data are available and the way in which the data is contributed are listed in appendix C.

As is clear from annex C, most AFFSC(E) members now are contributing to the database. Apart from those of SHAPE, bird strike data are received on a regular basis from 9 countries. No data have yet been received from TuAF, HAF, and PoAF; while contributions from USAF(E) and SAF did only have an incidental character.

The acceptance of the project of the European Military Bird Strike Database by AFFSC(E) members has been extremely important. It meant that the project could start with a fair number of contributors. Taken into account that flight safety is important to all Forces, extension of the circle of contributors with Air Forces not joining AFFSC(E) has to be considered. Recent political changes certainly make the participation of all European countries in the joined database seem a realistic option.

Hopefully, the availability of the new Form and the computerprogram as such will not only affect standardization of the contributing Forces but also of others, and thereby will enforce the comparability of bird strike statistics.

5. REFERENCES

1 Buurma, L.S. (1984); Key factors determining bird strikes and risks. Int. J. of Aviation Safety, Vol.2,no.1, pp. 91-107.

2. Dekker, A. & L.S. Buurma (1990); Towards a European Database of Military Bird Strikes. 20th Meeting Bird Strike Committee Europe, Working Paper 14. Helsinki

3 Jorgensen, H.I. (1958); Nomina Avium Europaearum. Copenhagen

EUROPEAN MILITARY BIRD STRIKE FORM

01. Adm. number ....

02. Incident date ....

03. Incident time ....

04. Unit/Squadron ....

05. Aircraft type ....

06. Speed ....

07. Altitude ....

08. Lat. Long. Coörd ....

09. Geogr. Location ....

....

10. Flightphase:
- ☐ Taxying
- ☐ Take-off
- ☐ Climb
- ☐ Low level, En-route
- ☐ Cruise
- ☐ Holding, in circuit
- ☐ Descent
- ☐ Final Approach
- ☐ Landing
- ☐ Touch and go, Overshoot
- ☐ Unknown

11. Operational effects: ☐ Unknown ☐ No ☐ Yes.........
- ☐ Aborted take-off
- ☐ Returned to base
- ☐ Landed at nearest airbase, being:

12. Crew injury: ☐ Unknown ☐ No ☐ Yes

13. Damage to aircraft: ☐ Unknown ☐ No ☐ Yes

14. Bird Strike noticed by: ☐ Unknown ☐ Pilot ☐ Groundcrew

	15. Impactpoint	16. Damagepoint		15. Impactpoint	16. Damagepoint
Radome	☐	☐	Canopy/windscreen	☐	☐
Nose	☐	☐	Fuselage	☐	☐
Wing	☐	☐	Landing gear	☐	☐
Rotor	☐	☐	Empenage	☐	☐
Air intake	☐	☐	Underwing Stores	☐	☐
Powerplant/Engine	☐	☐	Unknown	☐	☐

17. Type of bird ☐ Small (sparrow size) ☐ Medium (pigeon size) ☐ Large (duck size)

18. Bird remains collected ☐ Unknown ☐ No ☐ Yes

19. Bird identified by ☐ Unknown ☐ Pilot ☐ Gr.crew ☐ BCU ☐ Laboratory

20. Bird species: ....

21. Bird Number ☐ Unknown ☐ Single ☐ Flock, (number:)

22. Pilots remarks:

ADDITIONAL INFORMATION

23. Pilots name ....

24. Pilots reg. number ....

25. Aircraft reg. number ....

26. Engine reg. number ....

27. Costs .... Including manhours? ☐ Yes ☐ No ☐ Unknown

28. Man hours spent in repair ....

29. Classification (if applicable) ....

30. A/C Lights ☐ Unknown ☐ Off ☐ On

31. On board radar ☐ Unknown ☐ Off ☐ On

32. BIRDTAM ☐ Unknown ☐ No ☐ Yes, namely..............

33. Light conditions ☐ Unknown ☐ Dawn ☐ Day ☐ Dusk ☐ Night

34. Conditions ☐ IMC ☐ VMC ☐ Snow ☐ Rain ☐ Clouds....../8 ☐ Visibility ....Km

35. Comments:

Appendix B

Structure and conventions of the European Military Bird Strike Database

ADMNUMBER, 15 pos. First 5 positions reserved for abbreviation of air force. If less then 5 positions hyphens up to the sixth position.
Abbreviations:

Belgium	BAF	Canada in Europe	CFE
Denmark	RDAF	Germany	GAF
France	FAF	Greece	HAF
United Kingdom	RAF	Netherlands	RNLAF
Italy	IAF	Norway	RNOAF
Portugal	POAF	Spain	SAF
Turkey	TAF	US Air Force Europe	USAFE
NATO-Shape	SHAPE		

It is possible to enter a specific country code as default-setting (option 4 in Main Menu). Airforce and adm. number are seperated by a '/' at the sixth position.

INCDATE, 8 pos. Date in European notation, DD/MM/YY.
Default setting: systemdate

INCTIME, 12 pos. Time of birdstrike.
Hours to be seperated from minutes by <.> to be followed by letter indicating timezone.
If incident time is unknown both begin and endtime of the mission can be filled in (seperated by a <->).

UNITSQR, 15 pos. Unit or squadron the aircraft belongs to

AIRCRAFT, 15 pos. Type of aircraft

ACTYPE, 3 pos. Not to be entered by the user but to be fed in the database afterwards by the custodian. This field enables grouping of the data according to type of aircraft. The following types are reckognised:

HEL	Helicopters
JET	Jet fighters/bombers
TPC	(Turbo) Propellor Cariers
JEC	Jet Engine Cariers
OTH	Other

SPEED, 3 pos. Speed in knots, unknown to be entered as 'UNK'.

ALTITUDE, 5 pos. Altitude in Ft., unknown entered to be as 'UNK'.

LATLONG, 14 pos Geographical coördinates, Degrees to be seperated from minutes by a dot. First latitude, followed by a letter (N or S); immidiately followed by longitude plus letter (E or W). The pair of coördinates is written in the file seperated by <->.

LOCATION, 40 pos. Description of location.

FLPHASE, 11 pos. Flightphase. A maximum of three codes to be filled in, seperated by dots. Abreviations:

Taxying	TAX
Take-off	TOF
Climb	CLI
Low level, En-route	LLE
Cruise	CRU
Holding, in circuit	HOL
Descent	DES
Final Approach	FAP
Landing	LAN
Touch and Go, Overshoot	TGO
Unknown	UNK

LOCENR, 3 POS. Field to be filled in afterwards in order to facilitate quick selecting. Classification possible of bird strikes into:

LOC	Local / on airfield
ENR	En-route
UNK	Unknown

OPEFFECTS, 3 pos. Only 6 abbreviations are allowed in the program:

UNK	Unknown
NO	No
ATO	Aborted take-off
RTB	Returned to base
LNA	Landed at nearest airbase
CRA	Crash

BASE, 15 pos. Only to be filled in if 'LNA' in 'opeffects', for any other operational effects the program keeps this field empty.

INJURY, 3 pos. Only **YES**, **NO** or **UNK**nown to be filled in. Default setting: NO

DAMAGE, 3 pos. Only **YES**, **NO** or **UNK**nown to be filled in. If no damage, the fields COSTS, MANHOURSIN and MANHOURS are set empty.

NOTICED, 3 pos.

Only three possibillities:

UNK	Unknown
PIL	Pilot
GRD	Groundcrew

IMPACTPNT, 15 pos.

Up to 4 threeletter codes (seperated by dots) can be filled in to indicate the impactpoint. Abbreviations used are:

RAD	Radome	NOS	Nose
WIN	Wing	ROT	Rotor
AIT	Air Intake	POW	Powerplant / Engine
CAN	Canopy / Windscreen	FUS	Fuselage
		LAN	Landing gear
EMP	Empenage	UST	Underwing Stores / Tanks
UNK	Unknown		

DAMAGEPNT, 15 pos.

As Impactpnt

TYPEBIRD, 1 pos.

Indication on the type of bird involved, four entries possible:

S	Small, sparrow size
M	Medium, pigeon size
L	Large, duck size
U	Unknown

BIRDREMAIN, 3 pos.

Contains information on birdremains, i.e if remains were collected and who identified them. Only the following abbreviations:

UNK	Unknown wether birdremains were collected
NO	No birdremains collected
YES	Birdremains were collected

BIRDIDENT, 3 pos.

Contains information who identified the bird species involved.

UNK	Unknow	BCU	Bird Control Unit
PIL	Pilot	LAB	Laboratory
GRD	Groundcrew		

If no birdspecies is identified this field is normally to be left empty. It is however, possible that birdremains were collected and professional identification failse.

BIRDSPEC, 40 pos.

Bird species, any text is allowed but preferably the Latin Bird Name Generator (see 5.2) is to be used.

BIRDNR, 3 pos.

Opportunity to indicate number of birds that were involved.

UNK	Unknow
SIN	Single bird
FLO	Flock
999	Number

PILOTRMARK, 1 pos.

With a simple Y or N it is indicated wether pilot remarks are stored in the sisterfile.

PILOTNAME, 30 pos.

Pilots name. In case of dual aircraft only first pilot

PILOTREGNR, 12 pos.

Pilots registration number.

ACREGNR, 7 pos.

Aircrafts registration number ('tailnumber').

ENGREGNR, 12 pos.

Engine registration number(s).

COSTS, 16 pos.

Costs of birdstrike (2 decimals are used). Default setting 0.00

VALUTA, 3 pos.

Currency in which costs are expressed. Default setting is corresponding with the country code in the adm. number.

MANHRSIN, 4 pos.

Indicates wether manhours are included in the costs. UNK, INCL or EXCL. Default setting: INCL. In case the field DAMAGE is entered as NO, MANHRSIN is set to '-'.

MANHRS, 4 pos.

Number of manhours spent in repair. Default setting: 0

CLASS, 15 pos

Incident / accident classification.

ACLIGHTS, 3 pos.

Information on aircraft (landing) lights.
UNK, OFF or ON

ACRADAR, 3 pos.

Information on aircraft radar.
UNK, OFF or ON

BIRDTAM, 3 pos.

Information whether a BIRDTAM was valid at the time of bird strike. Possibilities: UNK, NO or YES. Default setting: NO

BIRDINT, 1 pos.

Only if the previous field BIRDTAM is YES, the actual bird intensity (1-8) can be entered in this field. If BIRDTAM was valid but intensity unknown a '9' can be entered.

LIGHTCOND, 3 pos. Information on the light conditions at the time of bird strike. The following entries are possible:

UNK	Unknown	DWN	Dawn
DAY	Day	DSK	Dusk
NGT	Night		

CONDITIONS, 8 pos. Meteorological information. At each specifis position a digit can be entered indication certain conditions.

First position values : U Unknown
- I IMC conditions
- V VMC conditions

Second position values : U Unknown
- S Snow
- \- No snow

Third position values : U Unknown
- R Rain
- \- No rain

Fourth position : Separating dot

Fifth position values : Cloud coverage in 1 to 8
Blank = no information

Sixth position : Separating dot

Last two positions : Visibility in Km.
Blank = no information
More than 10 Km = 10

Structure of the accompanying remarksfile

ADMINNR, 15 pos.

LINENUMBER, 2 pos.

PILOTTEXT, 70 pos.

Airforce	1988		1989		1990		1991	
RAF	C	694	A-from aug. C	 640	A E		A E	
GAF[1]	C	597	C D	 623	E		E	
RDAF	B	38	B	45	B	66	B	51
FAF			C jan/apr + oct/dec	80	C	91		
SAF			B from 23 june	19	B	12	B	4
IAF					A from april	45	A	87
CFE			C	71	C	50	C incompl.	6
USAFE	D	243						
RNLAF	D	195	D	243	D	183	D	89
BAF	C	116	C	116	C	95		
SHAPE[2]			C	21	C	24		
RNOAF[3]	D	38	D	38	D	36	D incompl.	8

Table 1:
A = Reporting has been incorporated in standard reporting system
B = Copies of BS forms are sent in (batchwise)
C = Computeroutput on paper or tables
D = Computerfiles on floppy disks available
E = Computerfiles on floppy disks imminent

1 Computerfile for the years 1979-1989 (5781 records) available.

2 For the years 1989 and 1990 tables available with (limited) data per bird strike, furthermore summary tables for the years 1983 - 1990 were received.

3 MacIntosh datafile available for the years 1985 up to may 1991. Total 191 bird strikes, of which 19 NON-RNOAF strikes

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BSCE 21/WP 10
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THE POTENTIAL OF LUMBRICIDE CHEMICALS FOR USE IN AIRFIELD BIRD CONTROL

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..TRACT

. the 20th meeting of BSCE, Allan and Watson (1990) presented data on the first ..ase of a two part study designed to investigate the potential of lumbricide ..rm killing) chemicals to reduce food supply available to birds from areas of ..field grassland where conventional long grass could not be grown. The second ..se of the study is now complete, and full details will be published ..ewhere. This paper summarises the findings of the whole study and discusses . potential benefits and drawbacks of the use of lumbricides to control bird ..hers on airfields.

. data suggest that lumbricide chemicals may have a limited potential for use ..bird control on airfields in the treatment of areas where the grass is kept ..t for operational reasons. Larger scale treatment is likely to result in a ..ber of difficulties in terms of the effective application of the chemical on .. grass swards, the possibility of short term attraction of birds to the ..ayed areas, the long term destabilisation of the invertebrate communities and . possible increased pesticide loading to the bird population on the ..field.

ACKNOWLEDGEMENT

The project was funded by the UK Civil Aviation Authority. Our sincere thanks are due to the management and staff of British Aerospace Military Aircraft Division, Samlesbury Lancashire for permission to use their airfield for this study and for their cooperation and assistance throughout.

1. INTRODUCTION

Almost all European airfields have significant areas of grassland which attract birds to feed and/or roost. In the UK the management of the grass sward to produce a thick growth of about 200mm in height is regarded as the most effective management technique to deter birds (Mead & Carter, 1973, Brough & Brigeman, 1980, CAA, 1990). This 'airfield long grass' is thought to deter feeding birds by making the detection of food items more difficult and to deter both roosting and feeding individuals by impeding their movement and by reducing their view of the surrounding area thus hampering detection of approaching predators. Good long grass is therefore particularly effective against birds which find food by sight in open grassland and also those species which rely on vigilance and flocking behaviours to avoid predators.

The bird species considered most hazardous to aircraft because of their body weight and flocking behaviour fall into the above category and are the 'priority group' of any aerodrome bird control programme (Milsom, 1990).

The most problematic birds in the priority group in the UK are gulls (*Larus sp.*) 36% of all birdstrikes and lapwings (*Vanellus vanellus*) 21% of all birdstrikes.

An alternative approach to habitat management of grassland in the aircraft movement area is to remove the food supply by applying pesticides. As earthworms comprise an important part of the diets of the most troublesome species, gulls and lapwings, there has been considerable interest in the potential of lumbricides, to reduce earthworm populations.

In the UK MAFF experimented with the insecticide chlordane during the 1960's. This is an organochlorine insecticide which kills earthworms. The results of the trials on airfield grassland were inconclusive in terms of bird control and highlighted the problem of pesticide residue persistence in the earthworms and on grass (Wright, 1968). It was suggested that less persistent alternatives, such as carbaryl might be employed. Chlordane is no longer approved for use as a lumbricide in the UK.

Other lumbricides have been tested on grassland on airfields overseas. In New Zealand, Caithness (1986) experimented with liquid and granular preparations containing endosulfan, while benomyl was tested at airfields in Canada and Finland (Tomlin & Spencer, 1976, Helkamo & Stenman, 1990). All these trials were successful, but neither of the active ingredients is approved for use as a lumbricide in the UK.

Of the two approaches, long grass cultivation or lumbricide treatment, long grass is currently preferred in the UK. The long grass technique deters a broad range of species, including those most hazardous to aircraft and crucially, it affects both feeding and resting individuals. Herbicides are occasionally applied to control weeds but otherwise pesticide inputs are relatively small. In contrast, lumbricides are more restricted in their scope. They will only reduce the food supply of those species which feed on earthworms and other soil invertebrates and have no effect on loafing and roosting birds. Moreover, there may be problems with the accumulation of pesticides or their

residues after repeated use. There appears be little difference between the costs of the two techniques.

In the light of the foregoing, there can be little justification for applying lumbricides over entire airfields. There are, however areas of airfields where the quality of long grass is poor because access for specialist cutting machinery is restricted, and other areas where the grass needs to be cut short for operational reasons (eg., around ILS installations or along runway margins). Such areas may be particularly attractive to birds, and in the case of runway margins, the presence of birds close to aircraft may be especially dangerous. A further problem encountered along runway margins is that of earthworms moving onto runways and taxiways in wet weather. Supplementary habitat management techniques may therefore be appropriate for use in these areas and, since most of the priority group species take earthworms as a major part of their diet (Cramp & Simmons, 1983), a habitat management technique which reduces the numbers of worms in areas of poor long grass or short grass was considered the most appropriate to test for this purpose.

Airfield grassland is defined as amenity grassland for the purpose of pesticide usage approvals in the UK. Two active ingredients were approved for use against earthworms in amenity grassland at the time of the experiment (MAFF, 1990). They were the organochlorine gamma HCH (also known as Lindane) combined with thiophanate-methyl and the carbamate carbaryl. Both of these chemicals are also broad spectrum insecticides and are therefore also likely to reduce the numbers of other invertebrates which form part of the diets of priority group species on airfields (Cramp & Simmons, 1983).

It was decided to test each of the available chemicals, one on grass which had been cut short by gang-mower and then allowed to grow to around 150mm to determine whether this technique would improve bird control on areas where proper long grass could not be grown, and one on short grass to simulate treatment of runway margins and areas around aircraft navigation aids.

The objectives of the study were as follows: Firstly, to determine how effective lumbricide chemicals are in reducing the numbers of worms in turf. Secondly, to determine how the changes in invertebrate numbers affected the number of birds which attempted to use the treated areas. Thirdly, to assess the impact of the lumbricide on other invertebrates. Fourthly, to determine how long invertebrate populations took to recover from the treatment and whether proximity to the edge of the treated area had any effect on this process.

2. METHODS

The study was conducted at British Aerospace Military Aircraft Division's airfield at Samlesbury, Lancashire UK. This airfield contained large expanses of short grass in the aircraft movement area which attracted very large numbers of birds. The combined densities of gulls, lapwings and golden plover (*Pluvialis apricaria* were so high that the likelihood of being able to detect effects of the lumbricides was good. The airfield had other advantages as a study site. It was secure and, as flying had ceased recently there was no bird control. The experiments were carried out in autumn and winter when bird numbers were highest.

In the first phase in 1989/90 a commercially available lumbricide containing gamma HCH plus thiophanate-methyl was applied by back-pack sprayer to three 1ha plots with a grass sward of 150mm. The grass on the airfield had previously been cut short twice with a gang-mower that year thus producing the kind of patchy sward which might occur on areas where the specialist machinery needed

to maintain proper long grass could not gain access. The three sprayed areas were compared with three adjacent 1ha plots which were unsprayed but otherwise managed identically.

The second phase of the study in 1990/91 was conducted using a lumbricide containing carbaryl applied by mechanical sprayer. A second set of plots was laid out in an identical way to that in the first phase, except that the grass on the plots was cut short two weeks prior to the application of the chemical in order to simulate the conditions around runway edges, ILS installations etc. The remainder of the airfield carried a similar sward to that in the first phase of the study.

The precise methodology for the sampling of invertebrate numbers and recording of bird numbers and behaviour for the first phase of the study has already been described (Allan and Watson 1990). The methodology for the second stage was identical with the exception of the change in chemical and the grass cutting regime on the experimental plots. In both cases bird and invertebrate numbers were monitored on the treated and untreated areas for 150 days after application of the chemical.

3. RESULTS

Detailed results for the first phase of the study were presented at the 20th meeting of the BSCE (Allan & Watson 1990), and the full data set for the entire experiment will be published elsewhere in due course.

This paper therefore, offers only a summary of the results obtained from both phases of the study, and concentrates on the feasibility of using lumbricides to aid aerodrome bird control.

3.1 The Impact of Lumbricide Treatment on Worm Populations

The treatment with gamma HCH in 1989/90 produced no discernible reduction in worm numbers in the treated area throughout the 150 days of the trial. This was thought to be because the chemical did not penetrate the longer grass cover effectively and did not reach the soil layer in sufficient quantity to be effective. Other workers have also encountered this problem, and Caithness (1986) overcame it by the use of a slow release granular preparation containing Endosulfan. Endosulfan is not approved for use as a lumbricide in the U.K., however (MAFF, 1990) and granular preparations of the two approved chemicals are not readily available.

The carbaryl treatment applied to short grass in 1990/91 produced a measurable reduction in worm numbers in the treated areas after 20 days which persisted to the end of the trial. This suggests that liquid lumbricides are likely to be most effective if applied to short grass areas.

3.2 The Impact of Lumbricide Treatment on Bird Numbers and Behaviour

Although there was some reduction in the number of birds using the treated areas of the plots in the first phase of the trial using gamma HCH on long grass, The number of birds using the experimental plots was low in this phase of the study and insufficient data were collected to allow statistical comparison.

The trial with carbaryl on short grass did show significant and potentially important effects of both the lumbricide and the grass cutting regime on bird behaviour.

Firstly, the act of cutting the grass short attracted large numbers of birds to the experimental areas both to feed and roost. At times, 80 to 90% of the 1500 to 2000 birds present on the airfield were concentrated on the short grass plots, compared to an expected value of 8% if the birds had distributed themselves evenly across the airfield. Feeding birds showed a greater preference for the short grass areas than did resting individuals. As the study progressed the proportion of the airfield population favouring the short grass areas fell.

Secondly, the chemical treatment significantly affected the food intake rate of lapwings feeding on the treated areas. Immediately after the chemical was applied, the rate of pray capture on the treated areas almost doubled as birds fed on moribund worms and other invertebrates which had come to the surface as a result of the pesticide application. At the same time, the proportion of feeding birds on the experimental areas which fed on the treated plots increased slightly, but this increase did not achieve statistical significance. Later in the study, the feeding rate of birds foraging on the treated plots fell to around half that of birds feeding on the treated plots and the proportion of birds occupying the treated areas also declined, but again not by a statistically significant amount.

3.3 The Impact of Lumbricide Treatment on Soil Surface Invertebrate Populations

Both of the treatments produced significant effects on the soil surface invertebrate communities, although there were some differences which may prove important in terms of bird control.

The gamma HCH treatment on long grass significantly reduced the numbers of all those invertebrate groups that were trapped in sufficient numbers to allow analysis. Numbers of adult beetles, beetle larvae and collembolans (springtails) fell after spraying, but recovered to their former levels after around 150 days. Spider numbers were also significantly depleted, but showed no sign of recovery throughout the period of the experiment. Large (over 3mm) and small (under 3mm) dipteran flies were both significantly reduced in numbers, but by the end of the experiment had recovered to the extent that they were more abundant in the treated areas in comparison to the control plots than was the case before the treatment was applied.

The carbaryl trial on short grass produced a similar reaction from beetles and collembolans, but the reduction in spider numbers was much less pronounced and the population had begun to recover by the end of the trial. Dipteran fly numbers were depressed initially by the treatment but their recovery was less marked than with the gamma HCH treatment, and numbers did not rise to levels greater than those before the treatment was applied.

Some studies (eg., Duffield & Baker (1990)) have shown that the rate of recovery of an invertebrate population is influenced by the distance to the nearest untreated area from which individuals might move. Comparison of the rates of recovery of invertebrate numbers for areas close to the edge of the plots with those at the centre showed no significant difference. This suggests that immigration of invertebrates from the untreated areas around the plots does not significantly influence the rates of population recovery in this case. Small areas of short grass, and particularly runway margins have a much higher ratio of untreated edge per unit area than does a large square plot and in these cases recovery may be speeded up by immigration of invertebrates from the surrounding long grass.

The effects of the two lumbricide treatments are summarised in tables 1 and 2.

4. DISCUSSION

The data show that lumbricide chemicals can be effective in reducing the numbe: of available food items for birds of the 'priority group' in airfield grassland, but they did not produce a corresponding reduction in bird numbers under the conditions of this experiment. They also highlight a number of significant difficulties likely to be encountered if large scale treatment or treatment of long grass is attempted.

4.1 Possible uses for Lumbricides on Airfields

The fact that the lumbricide failed to penetrate even a moderately dense sward of 150mm suggests that the only situation in which it is likely to be effectiv is when applied to short grass areas. The only time that airfield grassland should be cut short in the UK is during the bottoming-out process in March or a silage or hay crop is taken no later than early July (CAA, 1990). If the lumbricide is applied at these times, it is likely that recovery of the invertebrate populations will be well under way by the time of maximum bird infestation in late autumn and early winter, although this obviously depends o such factors as the timing of reproduction of the invertebrate species concern (Den Boer & Den Boer-Daanje, 1990). The foregoing, combined with the cost and environmental considerations, emphasise the fact that lumbricides are not a viable substitute for long grass in airfield bird control.

The lack of effectiveness when applied to a 150mm sward suggests that lumbricides are also unlikely to significantly improve the repellent propertie of areas where proper grass cannot be grown.

If lumbricides are not to be considered for large scale use on long grass area or for use on areas of poor quality grass, they may still be effective if applied to areas where the grass must be kept short for operational reasons su as runway margins or the areas around ILS installations. When applied to shor grass, the lumbricide effectively reduced the numbers of worms in the soil, an should, therefore, also help to reduce the problems caused by worms moving ont tarmac areas during periods of wet weather.

Although this study showed no increase in the rate of invertebrate population recovery close to the edges of the treated plots, other workers have shown tha invertebrate populations in areas close to the edge of a treated area recover more quickly from insecticide treatments due to immigration from the surroundi untreated habitat (Duffield & Baker, 1990). Runway margins have a particularl high ratio of untreated edge per unit area. For example, a 1km length of 2m wide runway margin has five times as much untreated edge per square metre than does an equivalent square area, even after allowing for the fact that the runw margin has tarmac on one side. It is therefore possible that recolonisation of small sprayed areas by invertebrates from surrounding unsprayed regions could reduce then effectiveness of lumbricide treatments. Although prey capture rate in the treated half of the plots fell in the latter stages of the trial, the proportion of birds using the treated areas did not show a significant decrease. This suggests that foraging on treated short grass is still sufficiently profitable to be worthwhile to the birds (improved predator detection may also influence the choice of feeding site). Further studies wou be required to quantify the long term effectiveness of treating runway margins with lumbricides.

.2 Possible problems resulting from Lumbricide use

: is important to note the practical implications of a temporary increase in od availability to the birds which resulted from the presence of large numbers dead or dying invertebrates caused by the application of the chemical to ort grass areas. If lumbricides are applied to short grass areas close to nways, it may be difficult to deploy the necessary extra scaring effort needed deter birds from such an easily available food supply.

nsideration should also be given to the ecological implications of the use of abricides on short grass areas. The fact that the prey capture rate lapwings almost doubled on the treated areas after the application of the emical suggests that the birds may be receiving an unacceptably high pesticide ading as a result of feeding on moribund invertebrates. Although an increased aring effort should reduce this intake, and the size of short grass areas is ely to be small, there is the potential for the delivery of sub-lethal doses or even poisoning of, non-target species. It is also possible that birds ich have received a sub-lethal dose of pesticide may be less able to avoid rcraft and thus more prone to cause birdstrikes.

further problem which may result from the routine use of lumbricides is the mulation of pesticides or their residues in the soil. Although gamma HCH is garded as one of the least persistent organochlorines (Anon, 1988) residues still present in soil up to one year later and accumulation may result if al applications are used (Leber, 1976). In what is an increasingly ironmentally conscious society, consideration should be given to both the tability and public relations implications of all pesticide treatments re they are applied.

The Effect of Lumbricides on other Invertebrates

pplication of a lumbricide to both types of sward was effective in reducing numbers of a wide variety of soil surface invertebrates. These rtebrates form a significant part of the diet of many of the 'priority p' species. Some airfield operators may be tempted to apply these or lar chemicals to long grass as a routine measure both to reduce the numbers vertebrates available in the grass sward and to prevent the emergence of ng insects such as crane flies (*Tipulidae*) which can attract aerial ing birds to forage above the airfield grassland. Such routine to ications of pesticides may do as much harm as good, however, since the ral predator prey balances in the invertebrate community may well be upted.

example, in the gamma HCH trail on a 150mm sward, the numbers of spiders significantly reduced throughout the period of the experiment and the ers of dipteran flies, one of the principal food items of the spiders ey, 1987), recovered to levels in excess of those present before the spray plied. In the second phase of the trial, using carbaryl on short grass, r numbers recovered quickly and dipteran fly numbers did not overshoot original levels. Spiders may consume up to 50% of emerging dipterans in land (Currey, 1987), which suggests that the higher numbers of spiders may kept the dipteran fly numbers in check. Duffield and Baker (1990) found a ar interaction between carabid beetles and collembolans, when the recovery collembolan population after insecticide treatment was restricted by the e of the predatory beetles. It is not possible to determine the cause of ifferent effect of the two chemicals on the spider populations. Carbaryl much shorter half life in soil than does gamma HCH (7 days compared to 4-6 Hotchkiss et al. (1989)), and this may have contributed to the more rapid ry of the spider population in the second phase of the trial.

It should also be borne in mind that the different grass cutting regimes and any difference in weather patterns between the two years may also have contributed to the differing results of the chemical applications. The results are, therefore, not conclusive evidence that the two chemicals have fundementally different effects.

5. RECOMMENDATIONS

a) The Aviation Bird Unit at the Central Science Laboratory will continue to recommend a full long grass policy as the best management technique for deterring birds from airfield grassland.

b) The use of lumbricide chemicals may be appropriate on grass areas which are routinely cut short for operational reasons, particularly if problems are encountered with worms moving onto runways in wet weather. On no account, however, should grass be cut short solely to apply a lumbricide treatment.

c) If lumbricides are applied, care should be taken to ensure that birds which may be attracted to the area to feed on dead or dying invertebrates are adequately dispersed, both to reduce the consequent birdstrike risk and to reduce the pesticide intake of the birds.

d) The routine application of pesticides to airfield grassland as an 'insurance' against the appearance of large numbers of temporarily abundant species should be discouraged.

6. REFERENCES

Allan J.R. & Watson L.A. (1990) The impact of a lumbricide treatment on the fauna of airfield grassland. BSCE 20/WP47.

Anon (1988) Agrochemicals Handbook 2nd edition Royal Society of Chemistry. London.

Brough T. & Bridgman C.J. (1980) An evaluation of long grass as a bird deterrent on British airfields. Journal of Applied Ecology 17:243-253.

Caithness T.A. (1986) A granulated insecticide to control invertebrates on airfields. BSCE 18/WP24

Civil Aviation Authority (1990) CAP 384 Bird Control on Aerodromes. U.K. Civil Aviation Authority. London.

Cramp S. & Simmons K.E.L. (Eds) (1983) The Birds of the Western Palearctic Vol. III. Oxford University Press. Oxford.

Curry J.P. (1987) The invertebrate fauna of grassland and its influence on productivity: 1 The composition of the fauna. Grass and Forage Science 42:103-120.

Den Boer P.J. & Den Boer-Daanje W. (1990) On life history tactics in carabid beetles: are there only spring and autumn breeders? 247-258 in The Role of Ground Beetles in Ecological and Environmental Studies. Intercept Ltd. Andover.

Duffield S.J. & Baker S.E. (1990) Spatial and temporal effects of the use of Dimethoate on populations of Carabidae and their prey in winter wheat. pp95-10[illegible] in The Role of Ground Beetles in Ecological and Environmental Studies. Intercept Ltd. Andover.

Helkamo H. & Stenman O. (1990) The Green Booklet: Some measures used in different countries for reduction of birdstrike risk around airports. 4th Edition. Birdstrike Committee Europe (Aerodrome Working Group). Helsinki.

Hotchkiss B.E., Gilbert J.W., Kamrin M.A., Witt J.W. & Craigmill A. (1989) Etoxonet. Cornell University.

Leber G. (1976) Verhaltem von Lindan in der umvelt Proceedings of the symposiu on Lindane in Lyon-Chazay 1976. C.I.E.L. Informations.

MAFF Health and Safety Executive (1990) Pesticides 1990 HMSO. London

Mead H. & Carter A.W. (1973) The management of long grass as a bird repellent on airfields. Journal of the British Grassland Society. 28:219-221.

Milsom T.P. (1990) The use of birdstrike statistics to monitor the hazard and evaluate the risk on U.K. civil aerodromes. BSCE 20/WP30.

Wright E.N. (1968) Modification of the habitat as a means of bird control. 97-105 in Murton R.K. & Wright E.N. eds. The Problems of Birds as Pests. Institut of Bioldogy Symposium No. 17. Institute of Biology. London.

TABLE 1

Summary of the effects on the bird and invertebrate fauna of airfield grassland resulting from the treatment of poor quality long grass areas with gamma HCH plus thiophannate-methyl

Species Group	Response
Earthworms	No reduction, probably due to lack of penetration to the soil layer.
Overall bird distribution and behaviour	Insufficient data.
Beetles	Numbers reduced, adult numbers recovered after 150 days.
Springtails	Numbers reduced, some recovery after 150 days.
Spiders	Numbers reduced, no recovery.
Dipteran flies	Numbers reduced, recovery to higher than previous levels.

TABLE 2

Summary of the effects on the bird and invertebrate fauna of airfield grassland resulting from the treatment of short grass areas with carbaryl

Species Group	Response
Earthworms	Numbers reduced.
Overall bird distribution	Birds concentrated on short grass.
Distribution of birds on plots	Some concentration on sprayed areas for first 14 days after spraying.
Lapwing feeding rates	Almost doubled on treated areas for 14 days after spraying then declined.
Beetles	Numbers reduced, little recovery.
Springtails	Numbers reduced, little recovery.
Spiders	Numbers reduced, rapid recovery.
Dipteran flies	Numbers reduced, recovery after 60 days.

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THE INFLUENCE OF TIDE AND WIND ON THE BIRDSTRIKE HAZARD AT COASTAL AERODROMES

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ABSTRACT

Information about the birdstrike hazard at coastal aerodromes suggests that the nature of the hazard and its severity may be different from that inland.

Advice given to airfields in the U.K. is largely based on research carried out at inland sites.

This paper presents data from a study commissioned by the U.K. Civil Aviation Authority into the nature and severity of birdstrike risk on coastal sites in the U.K.

Data are presented on how two factors, Tide and Wind, influence bird behaviour at coastal airfields.

The paper shows the problems encountered in the statistical analysis of time-series data and offers an alternative approach based on rule breeding computer algorithms.

The results show that tide state, height of the high tide, wind strength and wind direction can all influence the numbers of birds on airfields but that the importance of each factor varies between sites and bird species. Comparatively rare combinations of extremes of several factors are identified as most likely to cause severe birdstrike risk.

The report recommends that awareness of the way that environmental factors influence bird behaviour at coastal sites should be raised so that bird controllers can predict the combinations of factors likely to result in increased birdstrike risk at their own airfields.

ACKNOWLEDGEMENTS

This project was funded by the UK Civil Aviation Authority. We would like to express our sincere thanks to all airfields which cooperated in the survey, to the management and staff of Airfield Wildlife Management for their enthusiastic cooperation throughout the study, to the RAF for permission to undertake counts at their airfields, to the management and staff of British Aerospace Military Aircraft Division at Warton and to the management and air traffic control staff at Blackpool Airport for tolerating JRA's presence on their airfield for over a year.

1. INTRODUCTION

The Aviation Bird Unit at the MAFF Central Science Laboratory has been involved in research into the birdstrike hazard in the UK over the past 25 years. The bulk of this work has however, been conducted on inland airfields (eg., Allan & Watson 1990, Brough 1969, 1987, 1988, Brough & Bridgman 1980, Milsom 1990, Horton 1987, Horton et al 1983) and there are reasonable grounds for supposing that the hazard is different, and potentially more severe, on airfields near the coast (see below).

There is much evidence that the number and species of birds which frequent airfields are influenced by the surrounding environment as well as by the habitat on the aerodrome itself. Airfields in agricultural areas are surrounded by bird species which are adapted to take advantage of open country and are more likely to use flocking as a method of avoiding predators. Such species are likely to use airfield grassland to feed or rest and their flocking habit makes them especially dangerous to aircraft. In contrast, airfields situated in large tracts of woodland are surrounded by bird species which make less use of open grassland to feed and rely on the use of cover to evade predators (ABU unpublished). Such species are likely to make little use of airfields.

In the UK most coastal airfields lie next to agricultural land and so the open country species (gulls, plovers, corvids and pigeons) are augmented by those birds adapted to life on the coast, particularly shore waders and waterfowl (Prater 1981, Bowes et al. 1984, Evans 1984, Owen et al. 1986, Moser 1987. Like the inland agricultural species, coastal birds are adapted to life in open areas and rely principally on flocking behaviour to avoid predators. They can also be extremely numerous during autumn and winter (Lack 1986, Thom 1986, Hutchinson 1989).

Very few comprehensive data sets are available concerning the birds that frequent coastal aerodromes in the UK. The best is from RAF Kinloss in Scotland. This shows that the bird species which use the airfield correspond with those which as a result of ornithological census work are known to be present in the general area. Those species which occur commonlly on aerodromes throughout the UK such as gulls, lapwings and pigeons are joined by others such as Oystercatcher, Curlew, Dunlin, Redshank, Pink-footed and Greylag Geese which are scarce at or absent from airfields inland.

Unlike the situation inland, bird behaviour on or near the shore is strongly influenced by wind and tide. Birds are often thinly dispersed at low tide, accumulating in denser groups closer to the shore as the tide rises and forming large roosts over high tide (Hale 1980). Thus, the risk at a coastal airfield may vary within and between days as the birds' behaviour changes in response to cyclical changes in the time of high tide, tide height and less predictable factors such as wind strength and direction.

There is some evidence to suggest that the risk of birdstrikes involving flocks is greater at coastal sites, but it is not possible to carry out valid comparisons because of variability on reporting standards and bird control efficiency betweeen airfields (Milsom 1990).

In the light of the above, the UK Civil Aviation Authority commissioned a study to examine the relationship between the birdstrike hazard and aerodrome location and to determine how maritime environmental factors influence the nature of the hazard and the level of risk at coastal sites. This paper presents a summary of the findings in respect of two factors, tide and wind, and suggests how this information might be incorporated into advice given to bird controllers and managers on coastal airfields.

2. METHODS

2.1 The Choice of Sites for Detailed Study

The data gathered in a general survey of coastal aerodromes (Fig. 1) were used in the selection of sites for detailed study. Sites were chosen for a combination of scientific and operational reasons. Firstly, it was necessary to monitor a representative range of sites which reflected the variety of situations encountered in the general survey. Factors such as whether an airfield was on an open coast, an estuary or a cliff bound site and its geographical location in the British Isles (significant variations are found between bird populations from the north to the south of the country (Prater, 1981, Lack, 1986) had to be considered. Secondly, reliable data collection by trained observers was essential on those sites where ABU staff were not able to collect data in person.

Two airfields were selected for detailed study by ABU staff. These were British Aerospace Military Aircraft Division's aerodrome at Warton on the Ribble Estuary in Lancashire and the nearby Blackpool Airport on the Fylde coast (Fig. 1). The choice of these airfields allowed a detailed comparison of estuarine and open coast situations to be made between airfields only 10 km apart and where the overall pool of bird species was likely to be similar.

Daily counts were also made by staff from Airfield Wildlife Management Ltd, a bird control contractor, at a further five airfields: RAF Lossiemouth, RAF Kinloss, RAF Leuchars, RAF Machrihanish and RAF Chivenor. Of these Lossiemouth, Kinloss and Machrihanish are on open coasts, whilst Leuchars and Chivenor are principally estuarine. The location of each airfield is given in Fig. 1. Thus, a sample of seven airfields were studied at locations from Devon to Morayshire, representing habitat types from exposed open coast to muddy estuary.

2.2 Data Collection Techniques

In order to monitor how bird numbers and behaviour fluctuate within the tidal cycle at coastal sites, ABU conducted detailed counts at set time intervals at Blackpool and Warton. Counts were undertaken once per week at each airfield over 12 months and were timed to cover the high tide period (thought from previous experience to be the time at which birds were most likely to frequent the airfields). The counts were conducted at either hourly or two hourly intervals for an equal length of time before and after high tide. A standard transect of the site was covered for each count in order to ensure uniform coverage. Bird species, numbers and behaviour were recorded on each habitat type present at the sites as well as meteorological data and information on tide state, disturbance etc.,

At Warton, the survey was not conducted on the airfield itself, but on Warton saltmarsh, which lies immediately beneath the western approach.

Few birds frequented the airfield as a result of a good sward of long grass but, in common with a number of airfields close to estuaries, the approaches pass over areas of saltmarsh and grazing marsh which are managed as wildfowl refuges or nature reserves and where birds are numerous. This poses particular problems to bird controllers since scaring is frequently not permitted outside the airfield boundry (a similar situation exists at RAF Chivenor and at John F Kennedy Airport on New York; the latter has a particularly severe bird problem as a result (Seubert 1990)).

It was therefore thought more worthwhile to study the factors influencing the numbers and behaviour of birds in these approach areas at Warton. Counts were conducted on the aerodrome itself at Blackpool.

2.3 The Bird Species Studies

As coastal airfields are frequently close to both agricultural land and urban areas as well as the shore, they are likely to be used by an extremely wide variety of bird species. Some of these species may only frequent coastal sites whilst on migration, and may, therefore only occur on a particular airfield very infrequently. Although these species may pose a birdstrike hazard they are not suitable subjects for an intensive study of this type. This project concentrated on those bird species which occur on coastal airfields throughout most of the year, and particularly those of medium to high weight, which habitually form flocks and are thus regarded as the most dangerous to aircraft (the 'Priority Group' species (Milsom 1990)).

Numbers of the following priority group species were recorded at all of the study airfields:

Small Gulls	(*Larus sp.*)
Common Gulls	(*Larus canus*)
Black Headed Gulls	(*Larus ridibundus*)
Large Gulls	(*Larus sp.*)
Herring Gulls	(*Larus argentatus*)
Great Black Backed Gull	(*Larus marinus*)
Lesser Black Backed Gull	(*Larus fuscus*)
Oystercatcher	(*Haematopus ostralequs*)
Lapwing	(*Vanellus vanellus*)
Golden Plover	(*Pluvialis apicaria*)
Starling	(*Sturnus vulgaris*)
Curlew	(*Numerius arquata*)
Rook	(*Corvus frugilegus*)
Jackdaw	(*Corvus monedula*)
Carrion Crow	(*Corvus corone*)

In addition to the priority group species, number of other species or species groups which were either especially numerous at a particular site or whose behaviour was thought to be particularly influenced by such factors as tide and wind strength were also recorded. These species were not necessarily present at every study site. They were:

Greylag Goose	(*Anser anser*)
Shelduck	(*Tadorna tadorna*)
Mallard	(*Anas platyrhyncos*)
Redshank	(*Tringa totanus*)
Teal	(*Anas crecca*)
Woodpigeon	(*Columba palumbus*)
Feral Pigeon	(*Columba livia*)
Swallows and Swifts	(*Hirundinidae and Apodidae*)
Magpie	(*Pica pica*)
Grey Partridge	(*Perdix perdix*)
Raptor species	(*Accipitriformes* and *Falconidae*)
Small passerines	(*Passeriformes*)

2.4 Data Analysis and Presentation

In order to build a comprehensive picture of the bird hazard at coastal sites is necessary to collect extremely large data sets, which cover the wide range of environmental variables, such as tide state, height of the high tide, wind strength and direction, rainfall, atmospheric pressure, cloud cover, season o year and time of day, which might combine to affect the behaviour of birds at particular coastal airfields. The situation is further complicated by the possibility that the environmental factors could affect different bird specie in different ways. To address these questions the data set needs to be large include a sufficient number of all of the relevant combinations of environmen conditions to allow meaningful statistical analysis.

To present all of the data (a total of almost 1,500 possible combinations of environmental factor, bird species and habitat type for each site) is neither feasible nor desirable in a paper of this nature. This paper therefore focuses on the effects of two factors, tide and wind, on numbers of Lapwings Black-headed Gulls, the two most frequently struck species in the UK. A detailed discussion of the full data set will be published elsewhere.

Statistical analysis of data of the type collected in this study poses particular problems. The relationships between bird numbers and the environm variables measured are usually rather weak and, because none of the environmental variables acts in isolation, a complex and noisy data set results. Problems with nonlinearity and autocorrelated errors mean that multiple regression techniques are not valid for use on most of the data set, even with the appropriate transformations. The use of principal component analysis was considered but rejected because it was felt that linking variati in bird numbers to artificially created components of environmental variables would not be particularly meaningful to bird controllers and aerodrome managers.

To overcome these problems the BEAGLE (Biologically Evolving Algorithm Generating Logical Expressions) algorithm was selected (Forsyth, 1987). BEAGI incorporate developments in the fields of artificial intelligence to produce rule sets which describe a particular facet of a data set and then tests the predictive power of the rules it has generated using discriminant analysis techniques. Put simply, BEAGLE can be asked a question (eg., when are there more than 100 Lapwings on a particular airfield) and it will use the variables given to it to find a set of rules which best describes when the condition is true (eg., when winds are over 25 kts and there is less than 1 hour to high ti and it is raining). It also calculates how accurate the rule set it has produced is by testing its predictions against a subset of the data removed before the original rules were generated and determining how many times its predictions are correct.

This system has the advantage that it makes no assumptions about data structur normality etc., but most importantly it works in a similar way to the bird controller on the ground insofar as it can formulate a set of rules about wher birds are likely to be a severe problem in an airfield. One of the prerequisites of good bird control is that the bird controller should formulat

a similar set of rules for their airfield. The rules need not be formal mathematical ones, but to produce them requires the officer concerned to be aware of all of the environmental variables likely to affect bird behaviour and then to determine how those variables interact to influence bird numbers at the particular aerodrome concerned.

3. THE INFLUENCE OF TIDE AND WIND ON BIRD BEHAVIOUR

3.1 The Influence of Tide State

The effect of the tidal cycle on the distribution and behaviour of shore birds is widely understood by ornithologists. However, surprisingly few of those responsible for bird control at the civil airfields visited during the general survey were aware of the importance of this factor.

The tide might cause birds to move onto an airfield for two reasons. Firstly, by covering the available intertidal feeding areas causing birds to move onto the airfield in search of food or a place to roost, and secondly, by inundating shoreline or saltmarsh roosts, thereby forcing birds to move onto the airfield to find an alternative roosting site (Goss-Custard et al. 1977, Furness, 1973). The numbers of birds moving from the shore to an airfield to feed will be influenced by the availability of food in comparison with the surrounding area, and the numbers using it to roost by the degree of perceived risk on the airfield compared to alternative sites nearby.

The following figures show examples of how tide state affects the way in which Black-headed Gulls and Lapwings use Blackpool Airport and the approach areas at B.Ae Warton for both feeding and roosting.

Figs. 2(a) and 2(b) show data for Black-headed Gulls at Warton. There was a clear relationship between the numbers of both feeding and resting birds and the state of the tide. The highest numbers usually occured at high tide, but on most days no birds are present whatever the tide state. This suggests that other factors were combining with tide state to cause birds to move onto the study area. In this case, the height reached by the high tide was the critical factor (see 3.2 below).

Figs. 2(c) and 2(d) show the data for Black-headed Gulls at Blackpool. Here the pattern was slightly different from that at Warton. The highest numbers of birds were present on the rising tide, but numbers decended rapidly as soon as the tide began to fall. The pattern observed suggests that birds were being displaced from intertidal feeding and roosting areas by the rising tide and were then returning to feed on the newly exposed mudflats as soon as the water level falls. Early departure after high water would be favoured in order to maximise the time available to collect whatever food is left by the falling tide. The fact that few birds fed on the airfield throughout the tidal cycle indicated that the airfield grassland was a poorer feeding site for Black-headed Gulls than the intertidal areas nearby.

Figs. 3(a) to 3(d) show corresponding data for Lapwings. At Warton, there was a tendency for more birds to feed at high tide, but the trend was much weaker than that shown for Black-headed Gulls. More resting birds were present at hig tide than at other times. The situation at Blackpool was similar, with a weak relationship between feeding bird numbers and tide state, and a tendency for more resting birds to be present at high tide. The difference between species at the two sites is indicative of the ways in which birds make use of the two areas. Lapwings use both sites as preferred feeding and resting areas, with large numbers present throughout the tidal cycle, whilst Black-headed Gulls use

the sites as secondary feeding and resting sites at high tides, and in the case of Warton, high spring tides only (see below).

3.2 The Effect of the Height of the High Tide

The height of the high tide can have a profound effect on bird behaviour, particularly in estuarine areas with large expanses of intertidal mud and saltmarsh. Problems for the airfield bird controller can arise when high spring tides inundate the roosting or feeding areas of intertidal species and displace birds onto secondary habitats such as coastal airfields.

On a spring tide of over 9.8m the saltmarsh area at Warton is flooded at high tide and gulls moved onto the area in order to feed on food items flushed out of the vegetation by the rising water. As gulls are able to alight on water, they were able to remain on the saltmarsh to rest even when it was fully flooded. The high numbers of both feeding and resting birds were, therefore concentrated closely around the time of high tide (Figs. 2(a) and 2(b), but only on tides of over 9.8m in height (Fig. 4(a)). There was no similar effect at nearby Blackpool during the day (although a clear effect was found to occur at night during periods of strong onshore winds, see section 3.3).

Lapwings numbers were significantly influenced by tide height at Warton (Fig. 4(b)) with large numbers present on high tides of 9.5m in height, but few birds present on the highest spring tides when the saltmarsh was flooded and Lapwings were forced off to roost further inland. No effect of the height of the high tide on lapwing numbers was detected at Blackpool.

The BEAGLE rule sets which best predict when the total number of Black-headed Gulls will exceed 50 at Warton and when total gull numbers will exceed 200 at Blackpool illustrate this point. The best predictive rule at Warton is that the time until high tide is less than the time since sunrise or that the time of year is between February and September. The second best rule is that the height of the high tide is greater than 8.7m. Thus time of day, time to high tide, season of year and height of high tide are all predictors of high gull numbers. The rule set is not a particularly good predictor in the is case, however being correct on 65% of occasions when none of the rules are true. The rule set predicting when the total number of all gulls will exceed 200 at Blackpool shows the same environmental predictors of gull numbers as at Warton, except that rainfall and wind strength enter the equation as significant predictors. As Blackpool is an exposed coastal site it is not surprising that strong winds and accompanying rainfall will combine with tidal effects to cause birds to move to the airfield. As at Warton, the rule set is a relatively poor predictor, being correct on 60% of occasions.

The impact of tide height appears therefore to be heavily dependent on the kind of habitat surrounding the particular airfield concerned, the bird species present and the alternative feeding and roosting sites available locally in high spring tides.

3.3 The Influence of Wind Strength and Direction

As noted above, the strength of the wind might be expected to have a significant influence on the way that coastal birds behave. It is difficult, however to separate the effect of wind strength from that of wind direction at coastal sites. A strong onshore wind will increase wind chill for birds feeding or resting along an exposed shoreline, and may cause feeding or roosting sites to become inhospitable due to increased wave action. An offshore wind of similar strength may, however have far less impact on birds occupying what is a

comparatively sheltered shore. Such a sheltered area may, indeed be attractive to birds displaced from other more exposed sites.

Considering the significance which many bird controllers attach to wind streng[th] as a predictor of bird numbers, there proved to be surprisingly few instances where either wind speed or direction was correlated with bird numbers. Wind speed itself rarely influenced bird numbers directly, but did influlence the numbers of Black-headed Gulls resting and feeding at Blackpool (Figs. 5(a) and 5(b)). At Warton, wind direction influenced the numbers of Lapwings, Golden Plover and Starling feeding on the saltmarsh (Figs. 6(a) to 6(c)). More birds were present when the wind was from North East to South West ie., onshore than at other times.

The BEAGLE rule sets that predict when Lapwing numbers at Warton exceed either 500 or 1000 both contain rules which include wind speed of greater than 15 kts and wind direction between North-East and South-East as predictors of high numbers of birds. The rule sets do not identify wind speed or direction as predictors of Black-headed Gull numbers at Warton, but do show wind speeds of over 25 kts to be a predictor of high Gull numbers at Blackpool.

3.4 Complex Interactions of Factors

So far in this analysis each environmental factor has been treated separately. It is obvious, however that none of them operates in isolation. The way in which the various factors interact, and the relative importance of each one will inevitably vary from one airfield to another. This can be illustrated by comparing the BEAGLE rule sets which predict when Lapwing numbers will exceed 500 at Blackpool and Warton respectively.

The Rule Set for Blackpool is:

Rule 1 Wind direction is between South-East and North (ie., onshore), wind speed is over 12 kts and it is not January or February.

Rule 2 The height of the high tide is less than 8.8m.

This rule set correctly identifies 87% of cases of Lapwing numbers exceeding 500 when both rules are true.

The Rule Set for Warton is:

Rule 1 Wind speed is over 15 kts and the time of year is between September and March.

Rule 2 Total day length is less than 10 hours.

Rule 3 Height of the high tide is more that 7.4m.

Rule 4 The wind is between East and South-East.

The rule set is 100% correct in predicting Lapwing numbers of greater than 50[0] when all four rules are true.

Part of the reason that statistical models based on data collected over a lon[g] time period are relatively poor predictors of bird numbers is that simultaneo[us] occurance of extremes of several factors is comparatively rate and the effec[t] may be swamped by the rest of the data set. The rare situations when extrem[es] of environmental variables coincide are, however, the times at which exceptionally high bird numbers are likely to occur and effective bird contr[ol]

is most important. The BEAGLE algorithm is, therefore, particularly suitabl[e] for generating rules to predict when bird numbers are likely to be high and [t] risk of birdstrike at its greatest if appropriate action is not taken by the bird controller.

One example of this effect occurred at Blackpool during October 1990 when the highest spring tides of the year coincided with a period of south westerly (i[e] onshore) gales and heavy rainfall. Data collected during the general survey showed the wind direction, wind speed and rainfall significantly affected the numbers of gulls on the tarmac areas at Blackpool during the day. Observatio[ns] were undertaken to determine how such conditions affected behaviour at night.

Counts of the birds present on the airfield were undertaken hourly each night using an image intensifier for the five day period lup to the highest spring tide. During this time wind speed was about 30 kts, for the first four days [and] around 20 kts on the fifth day. Bird numbers increased each night as the hei[ght] of the high tide increased until the final night when the wind speed fell and bird numbers were lower despite a higher tide. The timing of the peak in numbers was about 40 minutes later each night coinciding with the time of the high tide.

Up to 6,000 gulls were present at the high tide count on the fourth night whic[h] would have posed a severe hazard had the airfield been operational. The combined effects of extremes of wind speed, tide height and tide state were no[t] detected by the general day time survey.

Although the data are too few for statistical analysis and the generation of a predictive model, bird control officers who were aware of the factors influencing bird numbers at coastal sites and who recorded bird numbers and th[e] combinations of environmental factors which produce them, would be able to anticipate future occurrences of similar situations.

CONCLUSION AND RECOMMENDATIONS

As well as being familiar with bird dispersal techniques, a good bird control officer needs to build a practical working model of how environmental factors interact at their own airfield to cause bird influxes. This allows them to predict the conditions when high bird numbers are likely to occur and to take appropriate action in good time to prevent the situation developing into a serious hazard. In order to construct such a model, bird controllers need to observe, identify and record bird numbers and behaviour on and around their airfields. These observations need to be made in relation to the full range of environmental conditions encountered at the site. Particular attention should be paid to situations when extremes of environmental conditions interact becaus[e] it is under these combinations of conditions that the highest bird numbers are likely to occur.

The general survey showed that the need for accurate recording of bird numbers and behaviour was not generally appreciated. An awareness of these factors that are likely to influence bird numbers on airfields was also frequently lacking. These shortcomings need to be addressed.

To that end we made the following recommendations:

All bird controllers at coastal airfields should be furnished with a set of local tide tables and encouraged to note any relationships between tidal an[d] weather conditions and bird numbers on the airfield.

2. To facilitate 1) above, all airfields should be required to keep detailed logs of bird numbers. Regular counts through the day, along with notes on weather conditions, tide state etc., will frequently bring to light patterns in bird behaviour not previously recognised by bird control staff. Such logs also prevent the loss of local knowledge which has been built up by one bird controller from being lost if he or she leaves the post.

5. **REFERENCES**

ALLAN J.R & WATSON L.A (1990) The impact of a lumbridice treatment on the fauna of airfield grassland. 20th. Bird Strike Committee Europe. Helskini working paper 531-541.

BOWES A., LACK P.C., & FLETCHER M.R., (1984) Wintering gulls in Britain, January 1983 Bird Study 31 161-170.

BROUGH T. (1969) The dispersal of Starlings from wodland roosts and the use of bio-acoustics Journal of Applied Ecology. 6: 403-410.

BROUGH T. (1987) Starling roosts and aerodromes. ABU report, Central Science Laboratory, MAFF, Worplesdon.

BROUGH T. (1988) The work of the Aviation Bird Unit. Symposium on Bird Hazards in Aviation, 14th. October 1987 London Royal Aeronautical Society.

BROUGH T. & BRIDGMAN C.J. (1980) An evaluation of long grass as a bird deterrent on British airfields. Journal of Applied Ecology 17: 243-253.

EVANS P.R. (1984) The British Isles. In: Evans P.R., GOSS-CUSTARD J.D. & HALE W.G. eds Coastal waders and wildfowl in winter pp261-275. British Ornithologists Union/Cambridge University Press. Cambridge.

FORSYTH R. (1987) PC/BEAGLE User Guide. Pathway Research Ltd, Nottingham.

FURNESS R.W. (1973) Roost selection by waders. Scottish Birds 7: 281-287.

GOSS-CUSTARD J.D., JONES R.E. & NEWBERRY P.E. (1977) The Ecology of the Wash 1. Distribution and Diet of Wading Birds (Charadrii) Journal of Applied Ecology 14: 681-700.

HALE W.G. (1980) Waders. Collins, London.

HORTON N. (1987) Bio-acoustic Bird Scarers (BABS). Civil Aviation Authority, London.

HORTON N., BROUGH T. & ROCHARD J.B.A. (1983) The Importance of Refuse Tips to Gulls Wintering in an Inland area of South-East England. Journal of Applied Ecology 20:751-765.

HUTCHINSON C. (1989) Birds in Ireland. T & A.D. Poyser, Calton.

LACK P. (1986) The Atlas of Wintering Birds in Britain and Ireland. T & A.D. Poyser, Calton.

MEAD H. & CARTER A.W. (1973) The Management of Long Grass as a Bird Repellent on airfields. Journal of British Grassland Society 28:219-221.

MILSOM T.P. (1990) Lapwings (*Vanellus vanellus*) on aerodromes and the Birdstrike Hazard. Ibis 132:218-231.

MILSOM T.P. (1990) The use of Birdstrike Statistics to Monitor the Hazard and Evaluate Risk on U.K. Civil Aerodromes. 20th. Bird Strike Committee Europe Helsinki. Working Paper 30:303-320.

MILSOM T.P. & ROCHARD J.B.A. (1987) Lapwings and Birdstrikes C.A.A. Paper No. 87015 Civil Aviation Authority London.

MILSOM T.P., ROCHARD J.B.A. & POOLE S.J. (1990) Activity Patterns of Lapwings (*Vanellus vanellus*) in Relation to the Lunar Cycle. Ornis Scandinavica 21:147-156.

..SER M.E. (1987) A revision of population estimates for waders (Charadrii) wintering on the coastline of Britain. Biological Conservation 39:153-164.

..EN M., ATKINSON-WILLES G.L. & SALMON D.G. (1986) Wildfowl in Great Britain 2nd edition, Cambridge University Press, Cambridge.

..ATER A.J. (1981) Estuary Birds of Britain and Ireland T. & A.D. Poyser, Calton.

..BERT J. (1990) Reducing Gull hazards to avaiation by controlling nesting populations. 20th Meeting Birdstrike Committee Europe. Working paper 54: 613-642.

..M V.M. (1986) Birds in Scotland T. & A.D. Poyser, Calton.

Figure 1. Map showing the location of the airfields visited during the initi survey of coastal sites (open squares) plus the location of the main study airfields (filled squares).

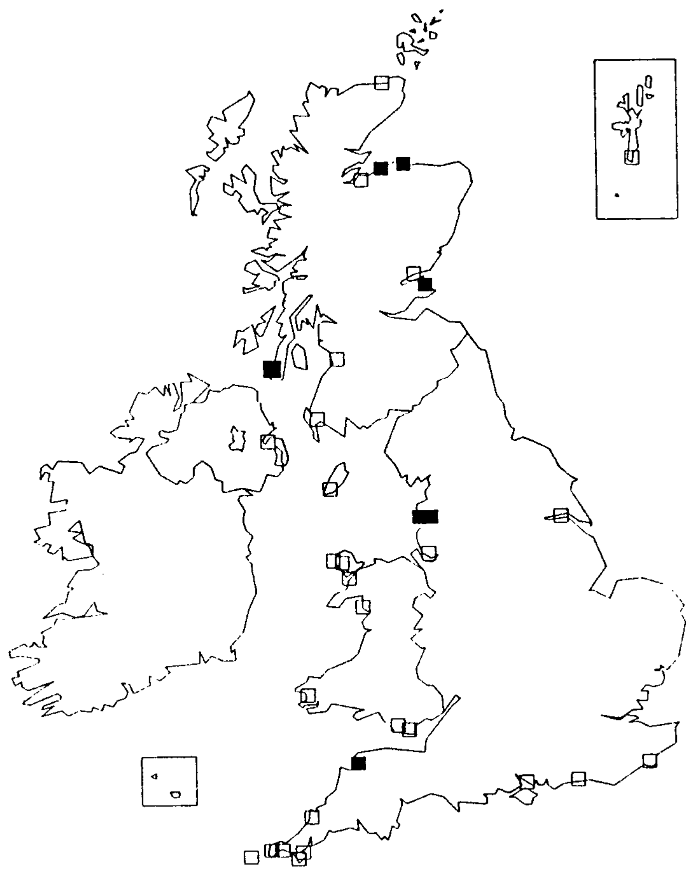


Figure 2. Scatterplots showing the numbers of feeding and resting Black-hea gulls present on the saltmarsh beneath the western approach to BAe Warton (a) and (b) and on the airfield grassland at Blackpool Airport (c) and (d) in relation to the time to high tide. Each data point shows the total recorded for an hourly count. A series of such counts were made before and after high tide at approximately weekly intervals for a year.

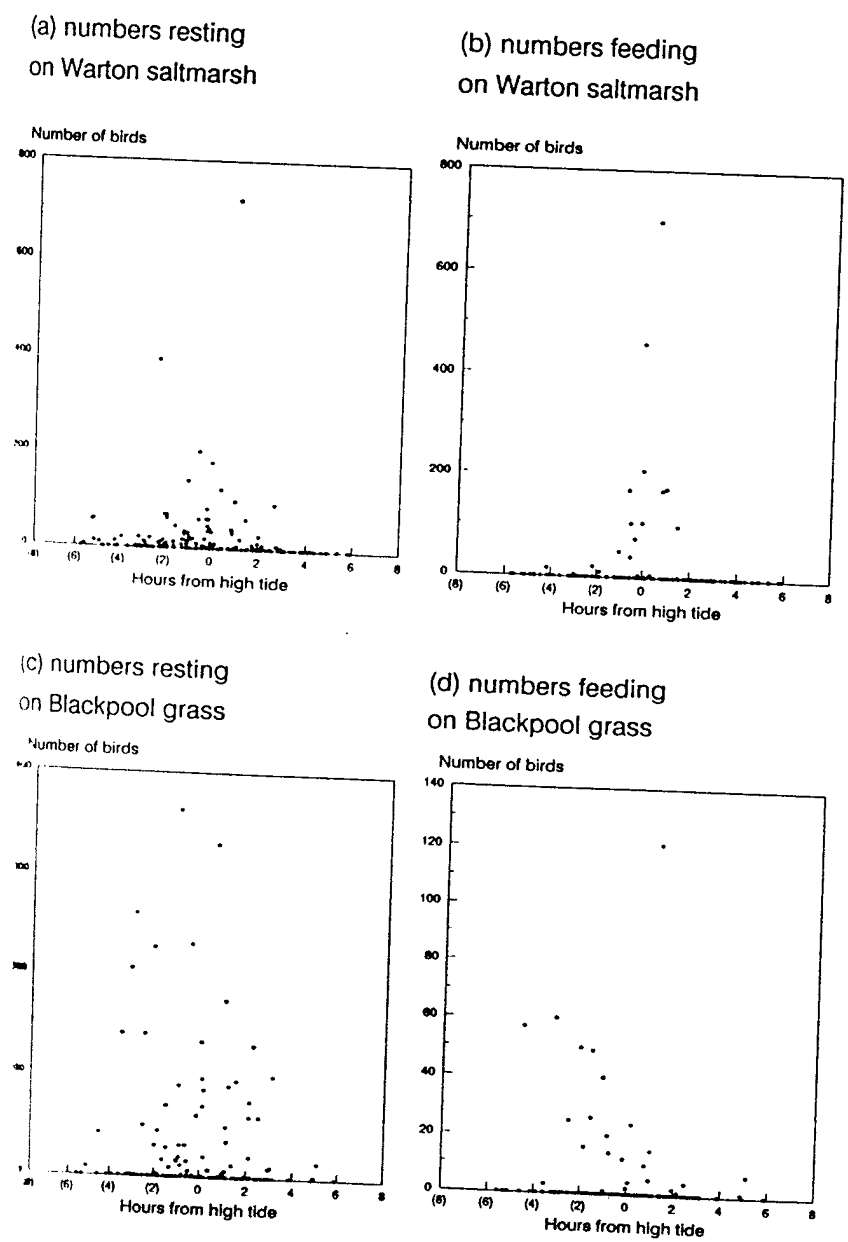
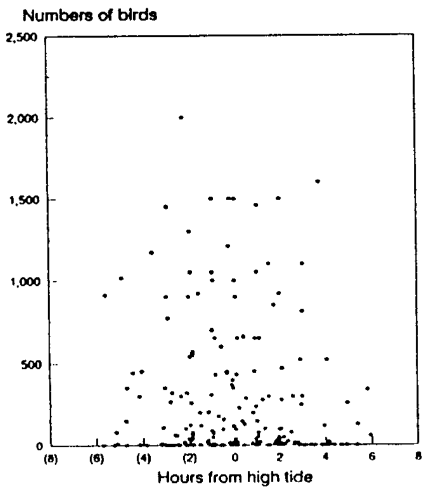
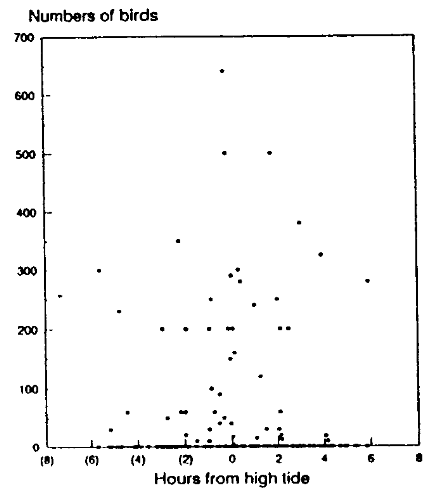


Figure 3. Scatterplots showing the numbers of feeding and resting Lapwings present on the saltmarsh beneath the western approach to BAe Warton (a) and (b) and on the airfield grassland at Blackpool Airport (c) and (d) in relation to the time to high tide. Each data point shows the total recorded for an hourly count. A series of such counts were made before and after high tide at approximately weekly intervals for a year.

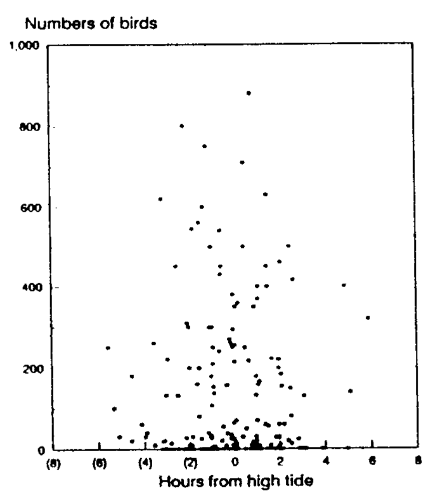
(a) numbers resting on Warton saltmarsh



(b) numbers feeding on Warton saltmarsh



(c) numbers resting on Blackpool grass



(d) numbers feeding on Blackpool grass

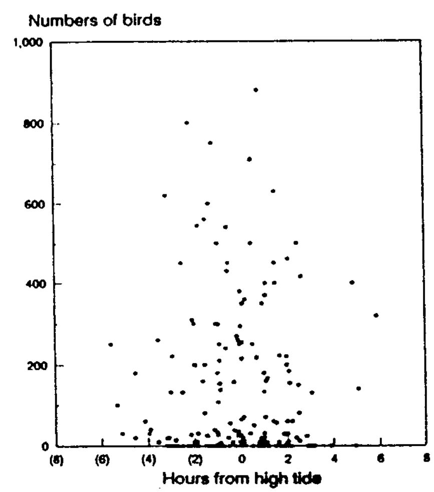
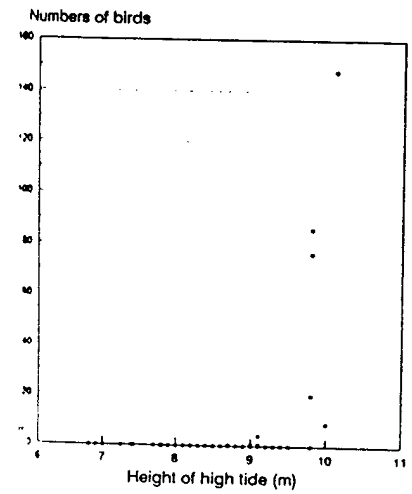


Figure 4. Scatterplots showing the numbers of feeding Black-headed gulls (a) and Lapwings (b) present on the saltmarsh beneath the western approach to BAe Warton in relation to the height of the high tide. Each data point shows the mean daily number present calculated from hourly counts. A series of such counts were made before and after high tide at approximately weekly intervals for a year.

(a) Black-headed gulls



(b)Lapwings

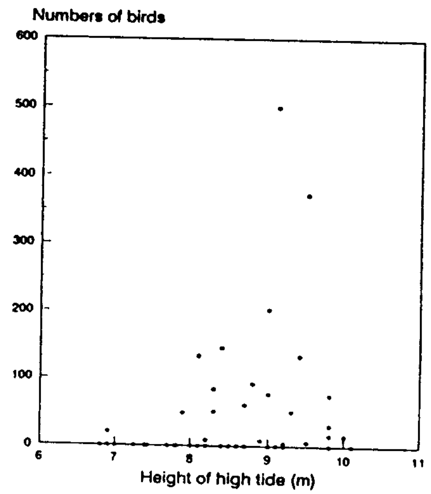


Figure 5. Scatterplots of the numbers of Black-headed gulls resting (a) and feeding (b) on the grassland at Blackpool Airport in relation to estimated wind speed. Data points show the numbers recorded on hourly counts conducted before and after high tide at weekly intervals for a year.

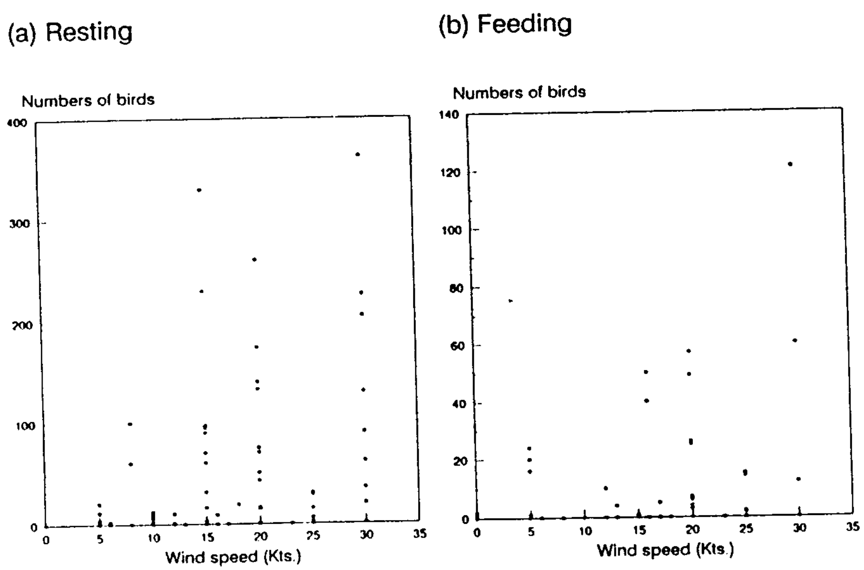
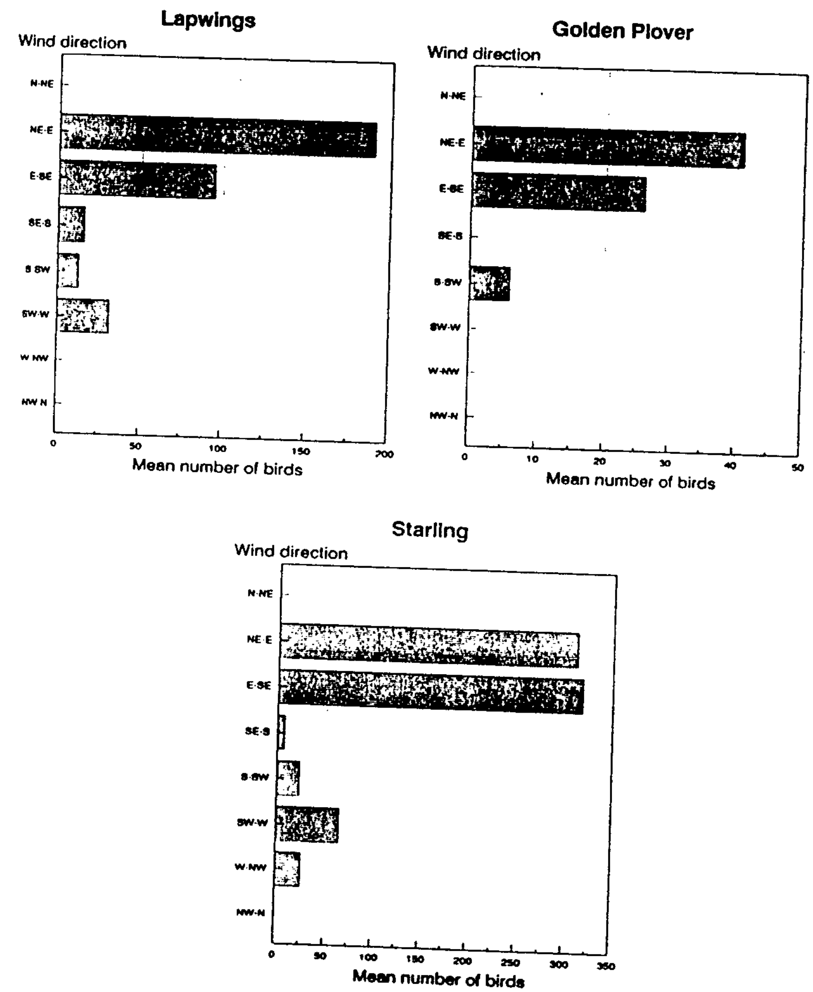


Figure 6. Histograms showing the mean numbers of Lapwings, Golden Plover and Starlings recorded on the saltmarsh beneath the western approach to BAe Warton in relation to the wind direction. Wind direction is categorised into eight sectors and the mean number of birds recorded from hourly counts taken around the high tide period on one day per week for one year is plotted.



BIOTECHNICAL DEVICES OF BIRD SCARING

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Riga, Latvia.

Abstract:

This paper summarizes the last ten years of research in the USSR with bioacoustic devices. Attention is paid to the construction of new generation microprocessor technology based synthesizers. The research has been carried cut by the specialists of the research team «Ptitsa». Recommendations as the use of bioacoustic devices at aerodromes are presented in the appendix. The added photos show the developement of the research.

In the 60ies and the 70ies the bioacoustic devices for bird control were constructed on the basis of mass-produced electric acoustic equipments meant for reproduction of speech or music. The first bioacoustic device (BAD) «Bars» constructed with the aim of bird scaring at aerodromes was accomplished in 1982 (photos 1,2). Research with these devices was carried out at several airports. The aim was to specify the standards for bioacoustic equipment series production.

The basic characteristics of the BAD «Bars» were the following: frequency coverage 0,3-18 kHz,maximum output power of the amplifier 180 W,maximum sound pressure 134 dB at 1 m distance on the loudspeaker axis. Two medium frequency and two high frequency horn loudspeakers constituted the loudspeaker system of BAD. The casset tape recorder used in the BAD had 30% tape speed acceleration and provided frequency coverage up to 20 kHz. Tests of BAD «Bars» with a signal handler (photo 15) showed that frequency coverage could be reduced to 0,6-7 kHz. That is explained by the fact that no component in the distress calls of bird species dangerous for aircraft (Laridae;Corvidae) are lower than 0,8 or higher than 7 kHz. The signal handler proved it necessary to introduce amplitude frequency predistortions in the transmitted signal.

Further on the BAD"Bars"was modernized (photo 3) by adding a digital synthesizer of «discomfort» signals. To obtain and tape distress calls from birds,namely, crows,an electric stimulation device constructed in 1985 (photo 16) was used. Impulses of voltage up to 300 V and frequency range from 2-20 Hz were transmitted to the electrodes. Amplitude and frequency of the impulses could be changed with the help of buttons on the front panel.

The research results helped in the construction of the series bioacoustic device «Bercut» (photo 4);production started in 1988. Simultaneously 8 different constructions of compact bioacoustic devices were worked out in the research team «Ptitsa» laboratory; of those BAD-8 (photo 7) was considered the most successful. Its characteristics were: maximum output power 120 W,frequency range 0,5-7 kHz,maximum sound pressure 134 dB at 1 m distance on the loudspeaker axis, voltage of the car battery 13,5 V. BAD-8 comprised a cassette tape recorder and discomfort signal synthesizer.The appendix gives recommendations for ornithologists as to its application.

The portable BAD-7 (photo 5) was meant for outdoors research. It comprised a synthesizer,outdoors player,and silver batteries for power supply,maximum output power 50 W. With the help of this device experiments on efficiency of different synthesized signals directed at flocks of birds were carried out in places difficult for access.

With the help of the vehicle-borne BAD-8 by way of regular gull distress call and added synthesized discomfort signal emission plus roof-based blinking orange and blue light signals a lake gull flock was eliminated from the vicinity of a monument by a pool. The maximum length of the signal was 10 s, repeated in case part of the birds returned.

A new,exceedingly powerful biotechnological device was manufactured and erected in 1990 at the Vnukova airport in Moscow (photo 9-11). It was meant for bird control on the territory of the airfield and adjacent territories. To achieve high speed of the procedure of bird scaring there were two acoustic systems installed bilaterally on the roof of a car (UAZ-452 B); the systems had 12 and 50 W horn loudspeakers. The total power of the amplifiers was 1,2 kW, and voltage from the battery of the car-13,5 V. The maximum sound pressure at the distance of 1 m from the loudspeaker heads-148 dB. This vehicle- borne device is the most powerful one in the territory of the USSR, and actually can claim to be recorded in the Guinness book of records as the loudest «scarecrow». The sound signals may be combined with flashes of light. When observing the device in action,it can be compared to a street-watering machine,only instead of dust brushed aside there are birds. Within a short span of time it was possible to free from birds a vast territory of the airfield.

For scaring birds from territories of pools a radio-controlled catamaran has been constructed (photo 12) with a built-in bioacoustic device, a synthesizer, and a moving model of prey bird. The operator manouvers the catamaran from the bank with the help of a long-distance control board built in a transmitter with code division of channels.

To assist the acoustic signals two radio manipulated flying bird of prey models were constructed in 1987 (photos 13,14). They differed in colour. Testing at aerodromes showed low efficiency,as they could be and operated only by a specialist on the condition of good weather. Disregarding the fact that the models imitated the flight of a hawk, birds showed fast habituation.

Beginning with 1982 great attention was payed to engineering of digital bird repellent signal synthesizers (photos 17-18). The characteristics of frequency, silent period length,frequency and depth of modulation frequency,the synthesized signal front growth speed,as well as the synthesized signals consisting of five formants could be changed (photo 18).

As a result of experiment series the kinds of synthesized discomfort signals, that work efficiently in scaring gulls, corvids and even pigeons,were stated.

New generation synthesizer was created in 1989 (photo 19-21). The test sample was the bioacoustic synthesizer «Skvorets» ("Starling"), emitting starling distress call coded with the help of timing frequency matrix. The equipment comprised a timer having phonation duration of up to 6 s for a silence period of up to 30 min. It was sufficient to locate the synthesizer «Skvorets» in bushes or on a tree and settle the emission period for 3 s and the off-period for 20min to keep thrush flocks away from the territory for some weeks. As the power use during the off-period is insignificant and the emission period is short, the batteries work for a month.

The newest equipment of this kind is a single chip microcomputer-based synthesizer (photo 22). Distress calls of gulls,corvids and starlings are

taped in the memory and can be chosen by pressing the corresponding button. It is also provided with stop and start buttons. In this synthesizer bird voices are transformed into a discreet impulse frequency by the delta modulation decoder MC3417 with discreditization frequency 64 kHz. Control is provided by a single chip microcomputer of the series 1816 which allows to form repellent signals of different length on the basis of a limited amount of EPROM stored information by way of compilation synthesis. The memory amounts to 64 kilobytes. The mikroscheme M2764 is used as memory equipment. It is possible to increase the amount of taped signals using instead a M27512 microscheme.

The programming of ROM microschemes is carried out on a microprocessing programmer (photo 23). For taping the acoustic signals of the birds in open air there exists a reflector microphone (photo 24) together with a signal processing equipment (photo 15) that let to achieve a quality phonogram of distresss calls without noise, useful for programming into the ROM.

Bibliography.

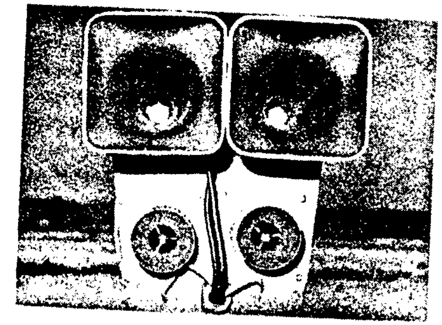
1.Ilyichev V.D. Birds deteriorating equipment,materials,raw materials, constructions over the USSR teritory.In Birds and Mammals Deteriorating Equipments and Constructions. M.Nauka,1990. pp7-141.

2.Birjukov V.Y.,Vjaznov A.E. Survey of bioacoustical complexes developed in the USSR. Baltic Birds-5. Riga,1990.Vol.1.pp45-48.

3.Birjukov V.Y. Handling of Aural Signals in Bioaccoustics.Engineering Ethology,Bioacoustics and Biolinguistics of Birds.M.Nauka,1991.pp50-56.

4.Birjukov V.Y. Minimization of Bioacoustic Synthesizers.Engineering Ethology, Bioacoustics and Biolinguistics of Birds.M.Nauka,1991.pp57-60.

1. THE FIRST SOVIET BIOACOUSTIC DEVICE (BAD) «BARS»



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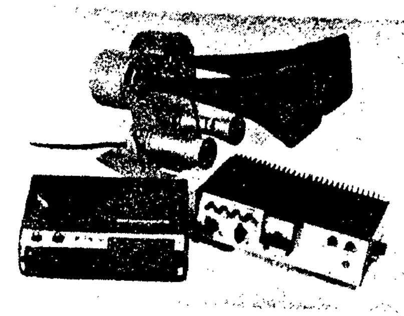

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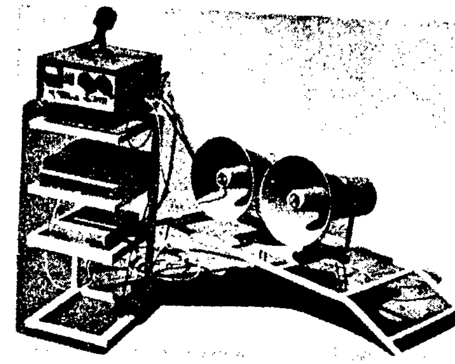

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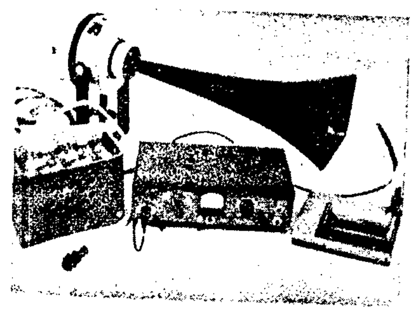
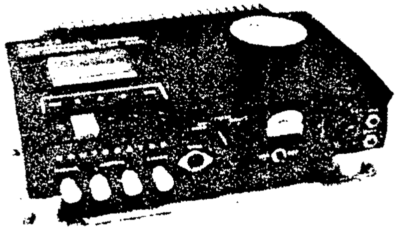


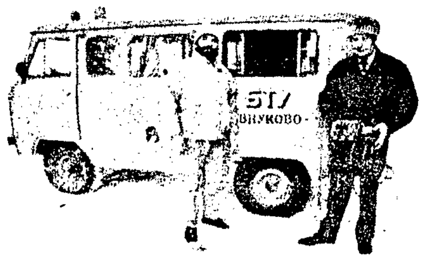
5. THE PORTABLE BAD-7

6. EXPERIMENT BAD-7



7. BAD-8

8. BAD-8 VEHICLE-BORNE VERSION



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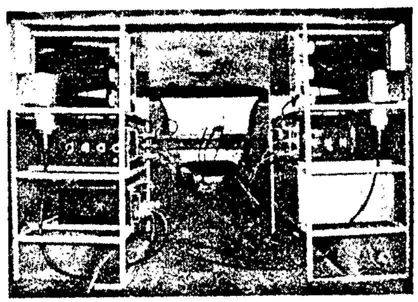

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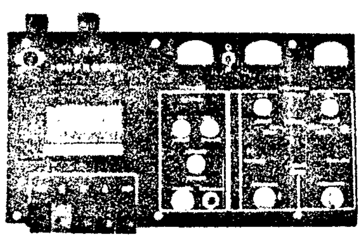
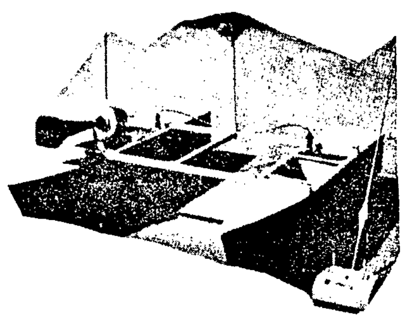


11. THE CONTROL BOARD OF THE BTD «VNUKOVO»



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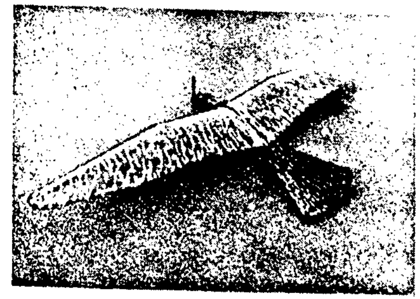
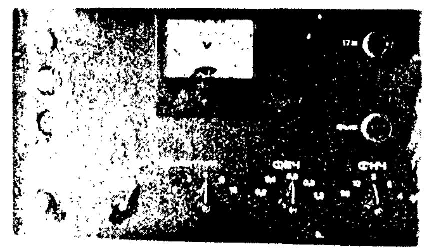


13. RADIO CONTROLLED MODEL OF A PREDATORY BIRD

14. MODIFICATION OF A RADIO—CONTROLLED MODEL



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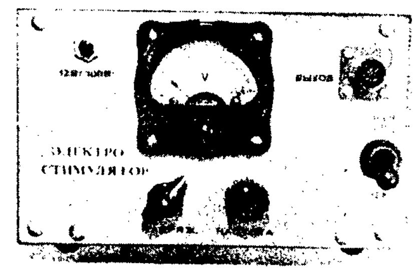

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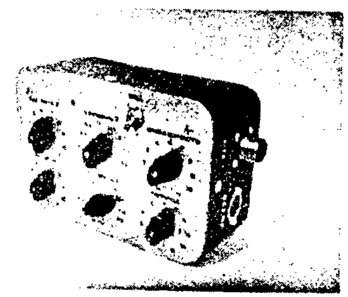
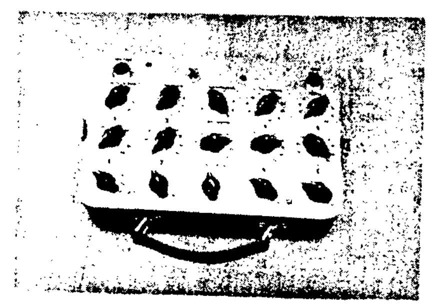


17. THE FIRST MODEL OF A SYNTHESIZER



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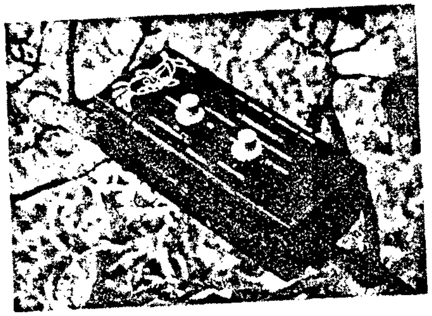

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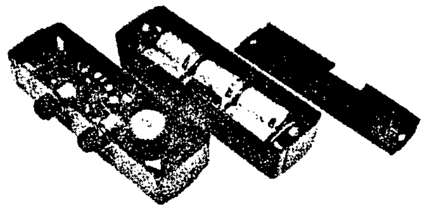

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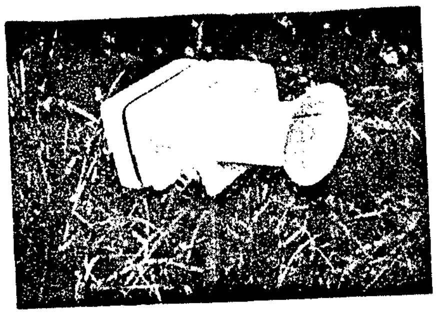

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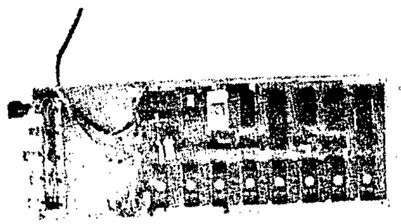
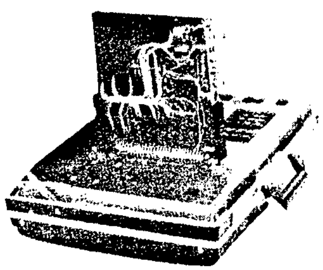
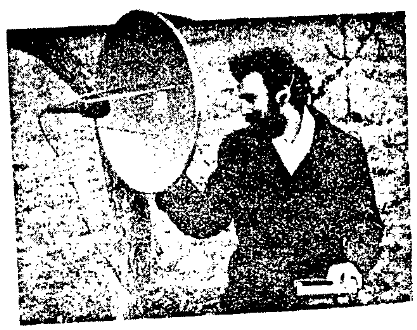


22. SINGLE-CHIP MICROCOMPUTER-BASED SYNTHESIZER



23. MICROPROCESSING PROGRAMMER



24. BIRD VOICE TAPING WITH THE HELP OF A REFLECTING MICROPHONE

RECOMMENDATIONS
USAGE OF THE VEHICLE-BORNE BIOACOUSTIC DEVICE BAD-8

1. The vehicle-borne bioacoustic device (BAD) allows to efficiently scare birds as well as tame and savage animals by way or distress and alarm call and syntethized repellent signal emission.

2. On condition the temperature exceeds 45 deg C the uninterrupted phonation period should not be more than 30 s.

3. It is most efficient to use BAD against flocks of birds.

4. Before emission it is required to approach the flock untill the distance is satisfactory and follow that the loudspeaker ax is directed at the birds.

5. The uninterrupted phonation period should not exceed 10-15 s to escape bird habituation. If the birds after taking wing and circling in the air try to return, it can be repeated 3-4 times. If that does not scare the birds away, it means that the bioacoustic signals do not function. The possible causes can be lack of correspondence between the distress (a regional or species difference), low quality phonogram or that the signal is not an alarm or distress call for the given species.

6. To help the distresss calls it is advisable to change them with discomfort signals, sirens and to shoot from flare pistols or guns.The flare pistols should not be aimed at the centre of the flock but at wings,taking into consideration the best direction for birds to leave.

7. The optimal silence period and repellent signal tone should be chosen through tests. There exists a correlation between bird size and the syntethized signal structure: the less the size,the more effective would be a shorter silence period and a higher tone.

8. If the operator lacks the signal tape of a certain species,it is possible to use syntethized discomfort signals and sirens as repellent signals. During the emission it is advisable to reach the maximum repellent effect by adjusting accordingly the potentiometer dials «Period»,"Frequency-1", «Frequency-2" and »Total". When emitting the discomfort signals it is advisable to start at a long silence period, then shorten it gradually with the help of the «Period» dial. The dial «Frequency-1" changes the lower formant frequency, the frequency increases, if the dial is turned clockwise. The dial »Total" ballances formant signal levels; the correlation is chosen through tests with the aim of optimal repellent effect.

9. Any distress call of Corvidae species is useful for scaring mixed flocks of these species.

10. For pigeons the repellent signal is craw voices and syntethized discomfort signals.

IMPROVING BIRDSTRIKE RESISTANCE OF AIRCRAFT WINDSHIELDS

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ABSTRACT*

USAF aircraft repeatedly prove that birds and aircraft cannot occupy the same airspace at the same time; over 3000 birstrikes per year cause millions of dollars in damage to USAF aircraft. On an average, these birdstrikes result in one aircrew member being killed per year and one aircraft being lost per year. More of these losses are due to birstrikes to the windshield subsystem than to any other subsystem. Windshield systems on several different aircraft are being redesigned to improve tolerance of the birdstrike event. Efforts to improve Birdstrike tolerance and reduce cost-of-ownership characteristics of these windshields will be discussed. Some technical voids in designing for, and integration of, birdstrike resistance will be discussed.

*Status report/working paper to be presented in fulfillment of responsibilities as member of Structural Testing Working Group at the Birdstrike Committee Europe Meeting, 22-28 March 1992 in Jerusalem Israel.

BSCE 21 / 14
Jerusalem, 23-27 March 1992

BIRD OBSERVATION SYSTEM SEMMERZAKE

BOSS91.

Cdt G. DUPONT and Cdt R. DEGRIECK

BELGIAN AIR FORCE

INTRODUCTION

...g the years 90-91, the Belgian Airforce developed a new system to ...ve and quantify bird migration through the use of radar and a ...ard PC. Before, the observation program was integrated in the ...tional ATC computer and had some limitations.

... actual system has the possibility to obtain radar information from 4 ... radars and 3 airfield radars, all located in Belgium. Two of the ... radars are 3-dimensional and give the capability of receiving the ... information of the bird migration.

... calculation of a "bird intensity" is based on a specially adapted ...ing program, and through the automation of the system it is ...le to calculate the intensity without the need for interpretation ... the user.

1. General description.

The system consists of a standard PC(AT) with color display, a plotter, a printer and a specially built interface for the task. The digital radar information is sent from the different radar sources to the PC via an interface, all information is converted to the same protocol and format. The radar data is sent to the PC for a fixed number of radar scans and is held on the PC. In this way, a number of radar data files are obtained to be used for the calculation of the bird intensity.

Unwanted plot information such as clutter, permanent echoes and aircraft are littered out by the tracking program.

The results are displayed on the screen in the form of birdtracks, they can also be displayed as an intensity, calibrated according to a logarithmic scale. This information can be either plotted or printed out.

2. Functional description.

The software has been developed to be used in a simple way through a number of program modules. The final results are displayed as a birdintensity for each GEOREF.

2.1. Read-in phase.

Digital radar information from different radars is read into a PC via an interface. These radar plot files are sequentially read in during 25 scans per file. The operator can specify the number and type of radars to be used and the start time of the read-in phase before the program begins.

2.2. Analysis phase.

During this phase the unwanted returns from the radar files are eliminated, this is achieved via the tracking program. This program can be adjusted by varying certain parameters such as minimum and maximum speed, scan to scan correlation, detection, ... to ensure that.
From the number of bird tracks and other tracking information, the computer calculates an intensity between 0 and 8 on the basis of a logarithmic scale.
The analysis module provides the possibility to manually track the plots to get, in case of doubt, more detailed information.

2.3. Additional utility programs.

Plotfile management routine.
Possibility to manually enter meteo information and radar settings.

2.4. Display facilities.

The following display possibilities are included:

a. presentation of the raw or the "cleaned-up" plotfile

b. zoom and off-centre functions

c. moving picture of bird track produced by fast replay of plot or track files

d. display of final results per GEOREF (i.e. number of plots and tracks per height layer, intensity per GEOREF, etc)

2.5. Printing and Plotting facilities.

The final results (intensity per GEOREF) can be printed out. In addition, it is possible to plot all tracks of the analysed radar data files together with a map of Belgium and the associated GEOREF squares.

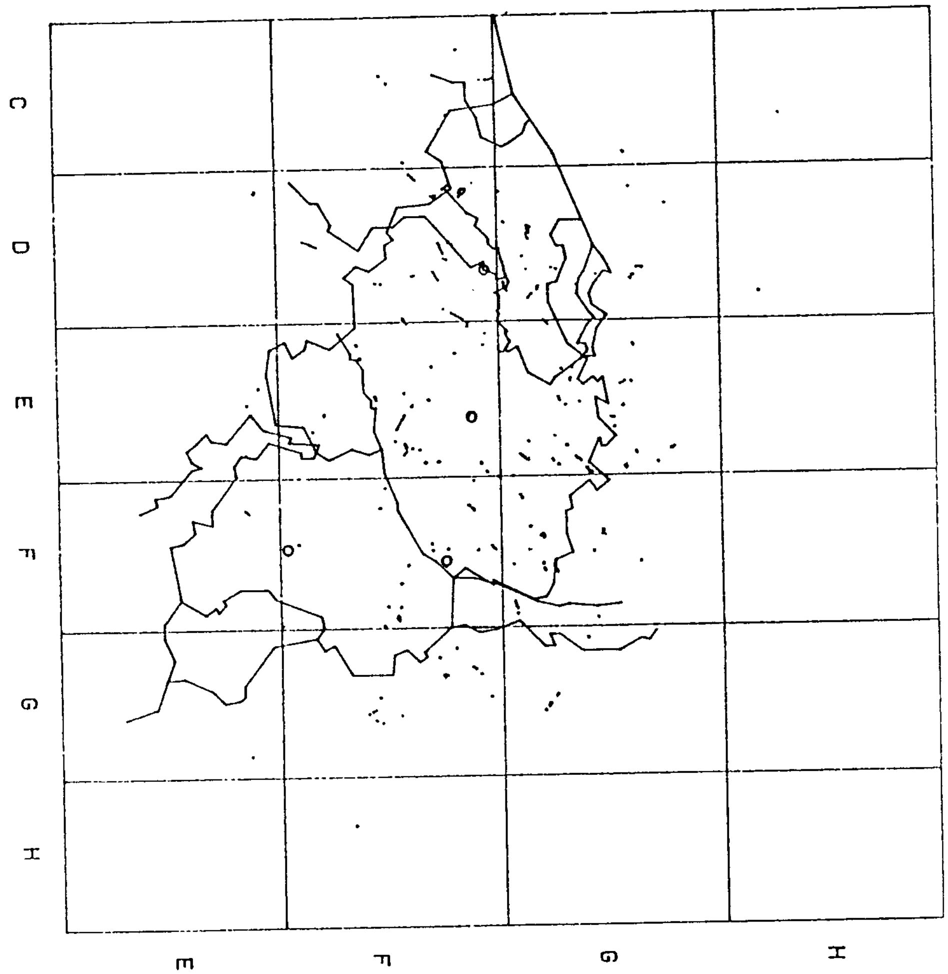
Actual situation and operational performance.

The system was calibrated during the spring 1991 bird migration and became operational in the autumn of 1991. The radar sensors are presently limited to 4 search radars from Belgium, Bertem and St.-Hubert (civilian 2D radars), Glons and Semmerzake (military 3D radars). In 1992, three supplementary airfield radars will be added to the system to improve the coverage.

In Annexes:

a. Plotting example of a processed radar file.

b. Bird intensity printout from the Semmerzake radar.



06-02-1992

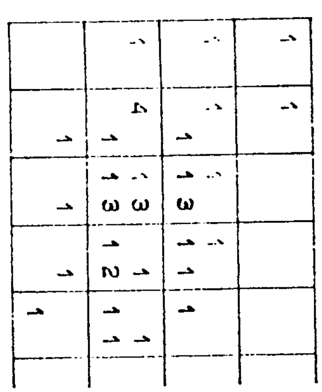
EBSZ1711.203

EBGL1711.263

EBSH1711.323

EBLV1711.373

INTENSITY



DATE ----------- : 06-02-1992
WIND DIRECTION - :
WIND SPEED ----- :
CLOUDS --------- :
VISIBILITY ----- :
TEMPERATURE ---- :
PRESSURE ------- :
RADAR STATION -- : EBSZ
RADAR SETTINGS - :
FILENAME ------- : EBSZ1711.203

CRF	>0 <2000 ft	>2000 <4500 ft	>4500 <8000 ft	>8000 <10000 ft	>10000 ft	TOT TRK	PLOTS	%MISSES	LENGTH	HEAD.	%ACCU.	INT
CH												
DH												
EH												
FH												
GH												
HH												
CG	0	0	1	0	0	1	2	0	2	53	100	1
DG	53	11	4	0	4	72	181	0	3	18	66	4
EG	2	5	10	6	0	23	54	0	2	45	69	1
FG												
GG												
HG												
CF	0	4	5	0	0	9	22	0	2	101	66	1
DF	43	21	21	1	1	87	224	0	3	48	68	5
EF	2	1	2	0	0	5	10	0	2	181	67	1
FF												
GF												
HF												
CE												
DE												
EE												
FE												
GE												
HE												

RDF 61? 96?

BSCE 21 / WP 15
Jerusalem, 23-27 March 19

RADAR CFAR THRESHOLDING IN CLUTTER UNDER DETECTION OF AIRBORNE BIRDS

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Latvia

ABSTRACT

The study of radar returns from birds is an interesting but rather neglected area of practical importance to radar operations, the hazard of collisions between birds and aircraft, and environmental monitoring, as well as to the subject of ornithology itself. The abundant radar returns from birds should not always be regarded merely as spurious signals to be eliminated from surveillance radar displays, but as useful signals to be made available for their utility in combating bird hazards and in environmental monitoring. This view, however, does not seem to be widely accepted as yet by radar engineers. Tests have shown that radar returns from birds can be readily distinguished from radar returns from automobiles and aircraft. With experience, an observer can distinguish large birds from small birds and perhaps make more subtle distinctions. This paper is concerned with the problem of statistical classification of radar clutter into one of several categories, including airborne birds, bats, insects, weather, and target classes, as well as the corrupting background noise. The problem can be separated into two parts. The first part, the problem focused on here, is to decide whether the received signal is signal plus noise (corresponding to the presence of any of various types of radar clutter corrupted by the background noise) or noise alone (corresponding to the presence of radar clutter excluding the corrupting background noise only). Noise is assumed to be Gaussian, but whose covariance matrix is totally unknown. The second part is the discrimination between various types of radar clutter corrupted by the background noise, i.e. classification of radar clutter into one of several categories. A solution to this problem has been presented in Nechval (1991) and will not be considered further. Radar detection procedures involve the comparison of the received signal amplitude to a threshold. The technique presented in this paper allows one to find a detection threshold that achieves a constant false-alarm rate (CFAR) in the presence of intensity changes in the noise background.

1. INTRODUCTION

The task of primary radars used in air traffic control is to detect all objects within the area of observation and to estimate their positional coordinates. Generally speaking, target detection would be an easy task if the echoing objects were located in front of an otherwise clear or empty background. In such a case the echo signal can simply be compared with a fixed threshold, and targets are detected whenever the signal exceeds this threshold. In real radar application, however, the target practically always appears before a background filled (mostly in a complicated manner) with point, area, or extended clutter. Frequently the location of this background clutter is additionally subject to variations in time and position. This fact calls for adaptive signal processing techniques operating with a variable detection threshold to be determined in accordance to the local clutter situation. In order to obtain the needed local clutter information, a certain environment defined by a window around the radar test cell must be analyzed.

Usually the background reflectors, undesired as they are from the standpoint of detection and tracking, are denoted by the term "clutter", and in the design of the signal processing circuits the assumption is made that this clutter is uniformly distributed over the entire environment. Signal processing is designed so that, whenever possible, target reports are received from useful targets only, rather than from background reflectors.

In practice, however, clutter phenomena may be caused by a number of different sources (such as airborne birds, bats, insects, or small clouds or other meteorological structures). Improvements in target detection and clutter suppression over the present state of the art can be effected only by removing the simplifying assumptions step by step and introducing a more differentiating way of argumentation. Ultimately it may become necessary to identify clutter regions of differing clutter type and to describe their properties such as type, size and borders, power, and spectral features rather than trying to suppress and ignore them at an early stage of signal processing. Thus for discriminating targets (such as aircraft) from clutter, it might be useful to build up a complete "image" of the clutter situation encountered in the overall observation space.

Unfortunately, real-time information on airborne hazards to aircraft, such as birds and storm systems, is also suppressed. The ability to classify clutter and hence identify these hazards can thus contribute significantly to air traffic safety.

These ideas reflect a trend presently observed in radar signal processing philosophy, a trend to regard the problem of target detection and clutter suppression more and more as a problem of image processing and image analysis. The procedure outlined in the following is one of steps in this direction.

In a radar system, the detection of signals in a background of stationary noise usually involves the comparison of a statistic, based on samples of signal plus noise, with a constant threshold that is determined from the noise-only probability distribution. The threshold is chosen so that a specified false-alarm probability is achieved, using the so-called Neyman-Pearson criterion. Unfortunately, in most cases the threshold depends on parameters of the noise-only distribution and, in practice, these parameters are actually unknown. If these parameters can be estimated from the available data, then the threshold can be determined (at least approximately) from the estimated parameters.

In a nonhomogeneous noise environment in which the average noise power varies in an unknown manner, it is impossible to maintain a constant false-alarm rate using a fixed detection threshold. In order to maintain a constant false-alarm rate (CFAR), it is necessary to utilize an adaptive threshold which can adjust to varying noise levels.

This paper is concerned with the problem of statistical classification of radar clutter into one of several categories, including airborne birds, bats, insects, weather, and target classes, as well as the corrupting background noise. The problem can be separated into two parts. The first part, the problem focused on here, is to decide whether the received signal is a signal plus noise (corresponding to the presence of any of various types of radar clutter corrupted by the background noise) or noise alone (corresponding to the presence of radar clutter including the corrupting background noise only). Noise is assumed to be Gaussian, but whose covariance matrix is totally unknown. The second part is the discrimination between various types of radar clutter corrupted by the background noise, i.e. classification of radar clutter into one of several categories, including airborne birds, bats, insects, weather, and target classes, if the received signal is a signal plus noise. The process of classification can be formalized as follows. The unprocessed radar data is passed through a feature extractor, which transforms the available data samples into a set of separable features. These features are derived from the reflection coefficients computed using the multisegment version of Burg's formula (Kay and Makhoul, 1983; Stehwien and Haykin, 1989). The aforementioned coefficients (that contain all spectral information, including the mean doppler shift) are then transformed and grouped to satisfy the requirements for multivariate Gaussian behaviour. Only information which is different from class to class is maintained, and in such a form that a reliable decision, based on a discriminant function derived from the above features, may be made. A solution to this problem has been presented in Nechval (1991) and will not be considered further.

The purpose of this paper is to present the procedure which allows one to find a detection threshold that achieves a fixed probability of a false alarm which is invariant to intensity changes in the noise background.

2. PROBLEM FORMULATION

Let $Z = (Z(1), Z(2), \ldots, Z(n))$ be a random sample formed of n independent and identically distributed clutter observations. On the basis of these observations we are to decide which of the following hypotheses is true:

H_0 (the noise-alone hypothesis):

$$Z(i) = Z^{\circ}(i) = (Z_1^{\circ}(i), \ldots, Z_p^{\circ}(i))' \sim N_p(0,Q), \quad i=1(1)n, \tag{1}$$

where Q is the unknown covariance matrix;

H_1 (the signal-plus-noise hypothesis):

$$Z(i) = Z^{\circ}(i) + bS(i), \quad i=1(1)n, \tag{2}$$

where $Z^{\circ}(i)$ is the vector representing all sources of noise-only processes,

$$S = (S(1), \ldots, S(n)) \tag{3}$$

is the signal pattern (an n-element row vector), and

$$b = (b_1, \ldots, b_p)' \tag{4}$$

is a (p x 1) vector of unknown signal intensities corresponding to the p features of the signal, respectively.

3. THE MAXIMUM LIKELIHOOD RATIO TEST

In order to distinguish the two hypotheses (H_0 and H_1) the maximum likelihood ratio testing procedure is used, where the probability density function of the sample data is maximized over all unknown parameters, separately for each of the two hypotheses. The ratio of these maxima is the detection statistic, and the hypothesis whose probability density function is in the numerator is accepted as true if it exceeds some preassigned threshold. The maximizing parameter values are, by definition, the maximum likelihood estimators of these parameters, hence the maximized probability functions are obtained by replacing the unknown parameters by their maximum likelihood estimators.

The maximum likelihood ratio principle is best described by a likelihood ratio defined on some sample space $\ddot{Z}$ with a parameter set $\ddot{\theta}$. Since

$$Q = E((Z(i)-E(Z(i)))(Z(i)-E(Z(i)))') \tag{5}$$

is the unknown covariance matrix of random vector Z(i) for i=1, 2, ... ,n, then for the current problem

$$\ddot{\theta} \triangleq \left\{ \theta=(b,Q):Q>0 \right\} \tag{6}$$

and the likelihood function is

$$L(Z;\theta) = \frac{1}{2\pi^{np/2} |Q|^{n/2}} \cdot \exp\left[-\frac{1}{2} \sum_{i=1}^{n} (Z(i)-E(Z(i)))' Q^{-1} (Z(i)-E(Z(i))) \right] =$$

$$= \frac{1}{2\pi^{np/2} |Q|^{n/2}} \exp\left[-\frac{1}{2} \mathrm{Tr}(Q^{-1}(Z-E(Z))(Z-E(Z))') \right], \tag{7}$$

where $|Q| \neq 0$ is the determinant of Q and

$$Z = (Z(1), \ldots, Z(n)) \tag{8}$$

is a p x n matrix of vector data Z(i) and Tr denotes the matrix trace function.

Let $\ddot{w}^{\circ}$ be the region in the parameter space $\ddot{\theta}$ specified by the H_0 hypothesis, then in terms of the complementary subsets $\ddot{w}^{\circ}$ and $\ddot{\theta}-\ddot{w}^{\circ}$ of $\ddot{\theta}$ define the alternative hypotheses H_0 and H_1 as follows

$$H_0 \equiv (b,Q) \in \ddot{w}^{\circ} \quad \text{and} \quad H_1 \equiv (b,Q) \in \ddot{\theta} - \ddot{w}^{\circ}, \tag{9}$$

where

$$\ddot{w}^{\circ} = \left\{ (0,Q):Q>0 \right\}, \tag{10}$$

$$\ddot{\theta} - \ddot{w}^{\circ} = \left\{ (b,Q):Q>0,\ b\neq 0 \right\}. \tag{11}$$

The maximum likelihood ratio test is given by

$$LR(Z) = \frac{\max\limits_{\theta\in\ddot{\theta}-\ddot{w}^{\circ}} L(Z;\theta)}{\max\limits_{\theta\in\ddot{w}^{\circ}} L(Z;\theta)} \quad \begin{matrix} \geq c, & \text{then } H_1 \\ < c, & \text{then } H_0 \end{matrix} \tag{12}$$

where $c \geq 0$ is the threshold of test.

It can be shown that

$$\max_{\theta\in\ddot{\theta}-\ddot{w}^{\circ}} L(Z;\theta) = \frac{1}{2\pi^{np/2} |\hat{Q}_b|^{n/2}} \exp(-np/2) \tag{13}$$

and

$$\max_{\theta\in\ddot{w}^{\circ}} L(Z;\theta) = \frac{1}{2\pi^{np/2} |\hat{Q}_0|^{n/2}} \exp(-np/2), \tag{14}$$

where

$$\hat{Q}_0 = \sum_{i=1}^{n} Z(i)Z'(i)/n = (1/n)ZZ', \tag{15}$$

$$\hat{Q}_b = \sum_{i=1}^{n} (Z(i)-\hat{b}S(i))(Z(i)-\hat{b}S(i))'/n$$

$$= (1/n)(Z-\hat{b}S)(Z-\hat{b}S)', \tag{16}$$

and

$$\hat{b} = \frac{ZS'}{SS'} \tag{17}$$

are the well-known maximum likelihood estimators of the unknown parameters Q and b under the hypotheses H_0 and H_1, respectively. Thus a substitution of (13) and (14) into (12) yields the maximum likelihood ratio test

$$LR(Z) = \frac{|\hat{Q}_0|^{n/2}}{|\hat{Q}_b|^{n/2}} \quad \begin{matrix} \geq c, & \text{then } H_1 \\ < c, & \text{then } H_0 . \end{matrix} \tag{18}$$

Taking the n/2th root, this test is evidently equivalent to

$$\dot{LR}(Z) = \frac{|\hat{Q}_0|}{|\hat{Q}_b|} \quad \begin{matrix} \geq k, & \text{then } H_1 \\ < k, & \text{then } H_0 \end{matrix} \tag{19}$$

where $k=c^{2/n}$. A substitution of (15), (16), and (17) into (19) produces the explicit test

$$\dot{LR}(Z) = \frac{|ZZ'|}{\left| ZZ' - \frac{(ZS')(ZS')'}{SS'} \right|} \quad \begin{matrix} \geq k, & \text{then } H_1 \\ < k, & \text{then } H_0 . \end{matrix} \tag{20}$$

To further simplify (20) note first that the inverse of ZZ' is shown to exist with probability one in the last paragraph of Appendix. Thus the test ratio in (20) can be considerably simplified by factoring out the determinant of the p x p matrix ZZ' in the denominator to obtain this ratio in the form

$$\dot{LR}(Z) = \frac{|ZZ'|}{|ZZ'| \left| I - (ZZ')^{-1/2} \frac{(ZS')(ZS')'}{SS'} (ZZ')^{-1/2} \right|}$$

$$= \frac{1}{1 - \frac{(ZS')'(ZZ')^{-1}(ZS')}{SS'}} . \tag{21}$$

The last equation follows from a well-known determinant identity. Clearly the test in (21) is equivalent finally to the test

$$W(Z) = \frac{(ZS')'(ZZ')^{-1}(ZS')}{SS'} \quad \begin{matrix} \geq w_0, & \text{then } H_1 \\ < w_0, & \text{then } H_0 . \end{matrix} \tag{22}$$

The result (22) is a CFAR test for a signal with unknown relative intensities corresponding to the p features, respectively. The

test under the assumption of unknown background clutter statistics has the CFAR property that the probability of a false alarm or its equivalent, the probability of signal detection, given the null or noise-only hypothesis H_0, is independent of the actual covariance matrix of the data. If p=1, the resulting test reduces to the standard normalized matched filter test for finding a signal in clutter of unknown and varying intensity.

4. DETECTION AND FALSE ALARM PROBABILITIES OF TEST

In order to find the probability density function of the test W in (22) on both hypotheses H_0 and H_1, one assumes the b and Q are known and start by noting that

$$\text{cov}(Z(i);H_l) = Q \qquad \text{for } l=0,1. \tag{23}$$

Also

$$E(Z(i);H_0) = E(Z^\circ(i)) = 0 \tag{24}$$

and

$$E(Z(i);H_1) = E(Z^\circ(i)+bS(i)) = bS(i) \tag{25}$$

or in terms of Z

$$E(Z;H_0) = 0 \quad \text{and} \quad E(Z;H_1) = bS. \tag{26}$$

Next perform a whitening procedure on Z(i) by defining

$$Y(i) = Q^{-1/2}Z(i), \text{ for } i=1,2, \ldots ,n, \tag{27}$$

i.e., let

$$Y = (Y(1), \ldots ,Y(n)) = Q^{-1/2}Z. \tag{28}$$

The whitening procedure in (27) and the assumption that $Z_j(i)$, i=1(1)n, j=1(1)p, are mutually independent produce the result

$$\text{cov}(Y_j(i)Y_s(r)) = d(j,s)d(i,r) \tag{29}$$

for j,s=1,2, ... ,p and i,r=1,2, ... ,n. Here d(i,r) is the Kronecker delta function defined by

$$d(i,r) = \begin{cases} 1 & \text{if } i=r \\ 0 & \text{otherwise} \end{cases} \tag{30}$$

and $Y_j(i)$ is the jth element of vector Y(i). Then by (26) to (30)

$$E(Y;H_0) = 0, \tag{31}$$

$$E(Y;H_1) = Q^{-1/2}bS, \tag{32}$$

and

$$\text{cov}(Y(i);H_l) = I_p \qquad \text{for } l=0,1, \tag{33}$$

where I_p is the p x p identity matrix.

Evidently by the transformation in (28) the test function in (22) becomes

$$W = \frac{(YS')'(YY')^{-1}(YS')}{SS'} \begin{array}{ll} \geq w_0, & \text{then } H_1 \\ < w_0, & \text{then } H_0. \end{array} \tag{34}$$

Since SS' is a positive scalar, at this point it simplifies matters to normalize the signal vector S by letting

$$S_1 = \frac{S}{(SS')^{1/2}} . \tag{35}$$

Then the test function in (34) becomes, using (35),

$$W = (YS_1')'(YY')^{-1}(YS_1'). \tag{36}$$

By (35) the sum-of-squares norm of S_1 is given by $\|S_1\| = 1$. Hence, S_1 is a unit row vector in the "direction" of vector S.

Now consider the n x n orthonormal matrix

$$U = \begin{pmatrix} S_1 \\ M \end{pmatrix} \tag{37}$$

where M is a (n-1) x n matrix, composed of some set of orthonormal row vectors, and such that

$$S_1M' = 0. \tag{38}$$

Hence the matrix U carries out rotations in n-dimensional space, in such a manner that unit vector S_1 is transformed into the new unit vector,

$$S_1U' = (1,0, \ldots ,0). \tag{39}$$

Now apply transformation U to Y by letting

$$V = YU' = (V(1),V(2), \ldots ,V(n)). \tag{40}$$

Then the test function W in (36) reduces to

$$W = V(1)'(VV')^{-1}V(1). \tag{41}$$

For more details on how U acts upon signal S_1 and Z or Y under H_1, see Appendix.

The covariance matrix of V(i), for i=1,2, ... ,n, is similar to that of Y(i), the only change of the statistics of the V(i) from that of the Y(i) is their mean values under hypothesis H_1. This mean is derived from

$$E(V;H_1) = E(YU';H_1)$$
$$= Q^{-1/2}bS_1U'(SS')^{1/2} =$$

$$= Q^{-1/2}b(1,0, \ldots ,0)(SS')^{1/2}$$
$$= (Q^{-1/2}b(SS')^{1/2},0, \ldots ,0). \tag{42}$$

From (29) and (42) a figure of merit or what might be termed the generalized signal-to-noise ratio (GSNR) is developed as follows:

$$GSNR = E(V'(1);H_1)E(V(1);H_1)$$
$$= (b'Q^{-1}b)\|S\|^2 \triangleq a. \tag{43}$$

Now consider a further simplification of the test function W in (41). First separate matrix V into two parts, V=(V(1),X) and X=(V(2), ... ,V(n)), in such a manner that

$$VV' = V(1)V'(1) + \sum_{i=2}^{n} V(i)V'(i)$$
$$= V(1)V'(1) + D. \tag{44}$$

Here

$$D = XX' = \sum_{i=2}^{n} V(i)V'(i) \tag{45}$$

is a nonsingular p x p matrix, since $n-1 \geq p$ and D is obviously Wishart distributed (see Appendix for more, but similar, details).

A well-known matrix inversion identity applied to (44) produces the result

$$(VV')^{-1} = (V(1)V'(1) + D)^{-1}$$
$$= \left[I - \frac{D^{-1}V(1)V'(1)}{1 + V'(1)D^{-1}V(1)} \right] D^{-1}. \tag{46}$$

A substitution of (46) into the test function W in (41) yields the test function W as the new expression

$$W = \frac{V'(1)D^{-1}V(1)}{1 + V'(1)D^{-1}V(1)} = \frac{W_1}{1 + W_1} \tag{47}$$

where

$$W_1 = V'(1)D^{-1}V(1). \tag{48}$$

It is desired now to find the probability density, $f(w_1;H_1)$, of W_1 in (48). First reexpress (48) in the form

$$W_1 = \|V(1)\|^2 \left[\frac{V'(1)}{\|V(1)\|} (XX')^{-1} \frac{V(1)}{\|V(1)\|} \right] . \tag{49}$$

Then normalize the p-component vector $V(1)$ as follows:

$$A(1) = \frac{V(1)}{\|V(1)\|} . \tag{50}$$

Hence by (50) one obtains W_1 in (49) in the form

$$W_1 = \|V(1)\|^2 (A'(1)(XX')^{-1}A(1)) = \|V(1)\|^2 q \tag{51}$$

where

$$q = A'(1)(XX')^{-1}A(1). \tag{52}$$

Now one can further process the term q in (52) by conditioning on the elements of $V(1)$ so that $A(1)$ can be treated as a normalized constant vector. Then since $A(1)$ has unity magnitude, there exists a p x p orthonormal matrix U_1 such that (see also Muirhead (1982))

$$U_1 A(1) = (1,0, \dots ,0)'. \tag{53}$$

Next apply this transformation to matrix X, defined before (44), by letting

$$H = U_1 X = U_1(V(2), \dots ,V(n)). \tag{54}$$

Then the term q in (52) has the simple form,

$$q = A'(1)(XX')^{-1}A(1)$$
$$= (1,0, \dots ,0)(HH')^{-1}(1,0, \dots ,0)'. \tag{55}$$

Clearly H in (54) has exactly the same statistical properties as X under the assumption that $V(1)$ is given.

Now partition H as follows:

$$H = \begin{pmatrix} H_A' \\ H_B \end{pmatrix} \tag{56}$$

where H_A is the (n-1)-column vector and H_B is the (p-1) x (n-1) matrix. Then

$$(HH')^{-1} = \begin{pmatrix} H_A'H_A & H_A'H_B' \\ H_BH_A & H_BH_B' \end{pmatrix}^{-1} = \begin{pmatrix} H_{AA} & H_{AB} \\ H_{BA} & H_{BB} \end{pmatrix} . \tag{57}$$

According to the Frobenius relations (Muirhead, 1982) for a partitioned matrix

$$H_{AA} = (H_A'H_A - H_A'H_B'(H_BH_B')^{-1}H_BH_A)^{-1}$$
$$= (H_A'(I - H_B'(H_BH_B')^{-1}H_B)H_A)^{-1}$$
$$= \frac{1}{H_A'(I - H_B'(H_BH_B')^{-1}H_B)H_A} = \frac{1}{H_A'RH_A} . \tag{58}$$

A substitution of (57) and (58) into (55) yields

$$q = \frac{1}{H_A'RH_A} \tag{59}$$

where $R=I-H_B'(H_BH_B')^{-1}H_B$ is a projection operator such that $R^2=R$ and $Tr(R)=n-p$. It is not difficult to show that R has n-p unity eigenvalues and p-1 zero eigenvalues. Thus R can be diagonalized to the form

$$U_2'RU_2 = T = \begin{pmatrix} I_{n-p} & 0 \\ 0 & 0_{p-1} \end{pmatrix} . \tag{60}$$

Under the assumption that $V(1)$ and R are given, one finds also that the random variable

$$1/q = H_A'RH_A = h'h = \sum_{i=1}^{n-p} h_i^2 \tag{61}$$

where q is defined in (59), and

$$h \triangleq T^{1/2}U_2'H_A \tag{62}$$

is a (n-1)-column vector with the last (p-1) components equal to zero. The conditional joint probability density function of the first (n-p) nonzero elements of h is subject to the normal density function, $N(0,I_{n-p})$, i.e.,

$$f(h_1, \dots ,h_{n-p};V(1),R) = N(0,I_{n-p}). \tag{63}$$

But also $f(\cdot;\cdot,\cdot)$ in (63) does not depend on $V(1)$ and R, so that h and 1/q in (61) must be statistically independent of the vector $V(1)$ and matrix R. Hence 1/q in (61) is chi-squared distributed.

Also by (51) and (59) one obtains the ratio W_1 in the form

$$W_1 = \frac{V'(1)V(1)}{h'h} = \sum_{j=1}^{p} V_j^2(1) / \sum_{i=1}^{n-p} h_i^2 . \tag{64}$$

Using the independence of vectors h and $V(1)$, one has the probability density function (see Miller (1964))

$$f(w_1;H_1) = e^{-\grave{a}/2} \frac{\Gamma(\frac{n}{2})}{\Gamma(\frac{n-p}{2})\Gamma(\frac{p}{2})} \frac{w_1^{(p/2)-1}}{(1+w_1)^{n/2}} {}_1F_1(\tfrac{n}{2},\tfrac{p}{2},\tfrac{\grave{a}}{2}\tfrac{w_1}{1+w_1})$$

$$= f(w_1;p,n-p,\grave{a}^{1/2}) \qquad (65)$$

of W_1 in (48) under hypothesis H_1 for $0 < w_1 < \infty$, where ${}_1F_1(a'',b'',x)$ is the confluent hypergeometric function. This is a noncentral f-distribution (Rao, 1965). The value $\grave{a}$ in Miller (1964) is given by

$$\grave{a} = \left\|E(V(1);H_1)\right\|^2. \qquad (66)$$

This agrees with the definition of the GSNR, $\grave{a}$, given in (43).

Finally by using the relationship of W_1 to W in (47) the probability density function of the test function W under hypothesis H_1 is given by

$$f(w;H_1) = e^{-\grave{a}/2} B(w;\tfrac{p}{2},\tfrac{n-p}{2})\ {}_1F_1(\tfrac{n}{2},\tfrac{p}{2},\tfrac{\grave{a}w}{2}) = B(w;\tfrac{p}{2},\tfrac{n-p}{2},\grave{a}^{1/2}) \qquad (67)$$

for $0 < w < 1$. This says that W is subject to a noncentral beta-distribution. Clearly, if no signal is present, then $\grave{a}=0$. Thus (67) reduces in the H_0 hypothesis to a standard beta-function density of form

$$f(w;H_0) = B(\tfrac{p}{2},\tfrac{n-p}{2})^{-1} w^{(p-2)/2} (1-w)^{(n-p-2)/2}, \quad 0 < w < 1. \qquad (68)$$

Finally, in terms of the above probability density functions in (67) and (68) the probability of a false alarm is found by

$$P_{FA} = \int_{w_0}^{1} f(w;H_0)dw \qquad (69)$$

and the probability of detection by

$$P_D = \int_{w_0}^{1} f(w;H_1)dw. \qquad (70)$$

APPENDIX

Properties of Orthogonal Matrix U

To see explicitly how orthonormal transformation U in (37) acts upon the normalized version S_1 of signal S in (3) and data matrix Z under H_1, the signal-plus-noise situation, let

$$Z \overset{\Delta}{=} b_1S_1 + Z^\circ \qquad (A1)$$

where $b_1=b(SS')^{1/2}$, $S_1=S(SS')^{-1/2}$, and Z° is data matrix Z when $b_1=0$ or hypothesis H_0 is true. Since

$$S_1U' = S_1(S_1',M') = (S_1S_1',S_1M') = (1,0,\ \dots\ ,0), \qquad (A2)$$

then a multiplication of Z in (A1) on the right by U' yields

$$V_1 = ZU' = (b_1S_1 + Z^\circ)(S_1',M')$$

$$= ((b_1S_1 + Z^\circ)S_1',(b_1S_1 + Z^\circ)M')$$

$$= (b_1 + Z^\circ S_1',Z^\circ M'). \qquad (A3)$$

Evidently the action of U on Z is to send signal b_1S_1 to $b_1(1,0,\ \dots\ ,0)$ plus a noise term $Z^\circ S_1$ into the first column only of the transformed data matrix V_1. The remaining n-1 columns of V_1, namely $Z^\circ M'$, constitute a signal-free p x (n-1) matrix from which, as it is shown next, an estimator of the covariance matrix Q can be found.

First note by the definition of V_1 and U that

$$V_1V_1' = Z(S_1',M')(S_1',M')'Z'$$

$$= (ZS_1')(ZS_1')' + (ZM')(ZM')'. \qquad (A4)$$

Finally under H_1 by (A3) one has

$$V_1V_1' = ((b_1S_1 + Z^\circ)S_1',Z^\circ M')((b_1S_1 + Z^\circ)S_1',Z^\circ M')'$$

$$= ((b_1S_1 + Z^\circ)S_1')((b_1S_1 + Z^\circ)S_1')' + (Z^\circ M')(Z^\circ M')'$$

$$= (ZS_1')(ZS_1')' + (Z^\circ M')(Z^\circ M')'. \qquad (A5)$$

The above identities (A4) to (A5) evidently establish the following relations:

$$(ZM')(ZM')' = (Z^\circ M')(Z^\circ M')'$$

$$= ZZ' - (ZS_1')(ZS_1')' \overset{\Delta}{=} G. \qquad (A6)$$

Taking the expected value of the left side of (A6) yields, by the use of the independence of the columns of Z,

$$E((ZM)(ZM)') = E((Z^\circ M)(Z^\circ M)') = (n-1)Q \qquad (A7)$$

where Q is p x p covariance matrix of the discrete vector process Z(i). This result shows that

$$\hat{Q} = \frac{1}{n-1}(ZM)(ZM)' \quad (A8)$$

is an unbiased estimator of Q with (n-1) degrees of freedom under both of the noise-only and signal-plus-noise hypotheses H_0 and H_1, respectively. Note finally by (Cramer, 1958) if $n-1 \geq p$ or $n > p$ that the $r=(1/2)p(p+1)$, distinct elements of $\hat{Q}$ are jointly Wishart distributed over the r-dimensional space of positive definite matrices. Hence $\hat{Q}$ in (A8) is positive definite with probability one.

The inverse of ZZ′ can be shown explicitly to likewise exist by noting the following:

$$ZZ' = G + (ZS_1')(ZS_1')' = (I + (ZS_1')(ZS_1')'G^{-1})G \triangleq KG. \quad (A9)$$

Evidently ZZ′ is invertible since clearly both factors K^{-1} and G^{-1} exist with probability one.

REFERENCES

Cramer, H. (1958). Mathematical Methods of Statistics. Princeton, NJ: Princeton University Press.

Kay, S.M. and Makhoul, J. (1983). On the statistics of the estimated reflection coefficients of an autoregressive process. IEEE Trans. on ASSP, vol. ASSP-31, pp. 1447-1455.

Miller, K.S. (1964). Multidimensional Gaussian Distributions. New York: Wiley.

Muirhead, R.J. (1982). Aspects of Multivariate Statistical Theory. New York: Wiley.

Nechval, N.A. (1991). Algorithm for statistical classification of radar clutter into one of several categories. SPIE Proceedings on Data Structurés and Target Classification (April 1991, Orlando, Florida USA), vol. 1470, Paper No. 1470-32, 12 pages.

Rao, C.R. (1965). Linear Statistical Inference and Its Applications. New York: Wiley.

Stehwien, W. and Haykin, S. (1989). A statistical radar clutter classifier. Proceedings of the IEEE National Radar Conference (March 1989, Dallas, Texas), pp. 164-169.

DETERMINATION OF NUMBER OF COLLISIONS BETWEEN AIRCRAFT AND BIRDS TO CONTROL RISKS OF ERRONEOUS JUDGMENTS ON THE BIRDSTRIKE HAZARD

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ABSTRACT

Birdstrike statistics are widely perceived as the primary instrument for monitoring the hazard and evaluating risk on individual aerodromes. However, those currently in use are not very informative and they are susceptible to variations in reporting standards. The primary goal of bird control on aerodromes should not be to prevent all birdstrikes but to minimize the likelihood of an incident that results in damage to the aircraft. A minimum acceptable standard for bird control has not been formally defined but the technique proposed in this paper forms the basis for discussion. The problem considered here is that of estimating the number of collisions between aircraft and birds to observe on each aerodrome to control the risks of erroneous judgments on the true MFTBSB (mean flying time between successive birdstrikes), and hence on the true birdstrike hazard. (It is assumed that an observed series of birdstrikes is a realization of a Poisson process.) An illustrative example is given.

1. INTRODUCTION

The research worker and statistician frequently deal with phenomena in which events of some type occur randomly in time. The Poisson process is the formal model of such phenomena.

The results of any experiment in which observation is performed continuously and "events" (i.e., occurrences of any specified kind) are tallied, can always be described by a function $x=x(t)$, which gives the number of events observed, x, during the first t units of observation, for all values of t from 0 through T, the total amount of observation performed. Such an experiment, yielding an observed function $x(t)$, is a Poisson process if the events occur randomly in the sense of the following natural definition: given that any number x of events are observed in any amount t of observation, the points of occurrence of the x events are randomly (i.e., independently uniformly) distributed between 0 and t.

An example in which the Poisson process is a very accurate and useful model is an observed series of birdstrikes.

A Poisson process can be characterized in the following two simple alternative and equivalent ways:

(a) The "waiting times" w between successive events are independently distributed with the exponential density function

$$f(w) = (1/\theta)e^{-w/\theta}, \quad w \geq 0. \tag{1}$$

Here θ is the mean of waiting times:

$$E(w) = \theta. \tag{2}$$

(b) The increment $y=x(t_2)-x(t_1)$ of $x(t)$ on any interval of length $l=t_2-t_1$ has the Poisson distribution

$$p(y) = e^{-gl}\frac{(gl)^y}{y!}, \quad y=0,\ 1,\ \dots, \tag{3}$$

and the increments of $x(t)$ on non-overlapping intervals are independent. Here gl is the mean increment on an interval of length l. Thus g is the mean rate of occurrences, and $g=1/\theta$.

All statistical questions concerning Poisson processes involve inferences about the value of the single parameter g or θ of one process, or about the values of the respective parameters of several processes.

Methods for determining whether a given process is Poisson will not be discussed here; Lewis (1965) describes and applies several methods.

2. THE MEAN FLYING TIME BETWEEN SUCCESSIVE BIRDSTRIKES (MFTBSB)

Our model of the flying time between successive birdstrikes is given by the exponential density (it is assumed that an observed series of birdstrikes is a realization of a Poisson process):

$$f(w) = (1/\theta)e^{-w/\theta}, \quad w \geq 0, \tag{4}$$

where w is the flying time between successive birdstrikes, θ is the true, unknown MFTBSB. It is well known (Epstein and Sobel, 1953; Nechval, 1984) that if we set a risk α of rejecting the null hypothesis $\theta=\theta_a$ (the acceptable value of MFTBSB) when true, and a risk β of accepting $\theta=\theta_a$ when actually $\theta=\theta_u$ (the unacceptable value of MFTBSB), where $\theta_u<\theta_a$, then the power function of the test, or the operating characteristic curves and hence the number of collisions between aircraft and birds (birdstrikes) s may be obtained from

$$\theta_a/\theta_u = \chi^2_{1-\beta}(2s)/\chi^2_{\alpha}(2s) \tag{5}$$

where $\chi^2_{\alpha}(2s)$ is the lower α probability level and $\chi^2_{1-\beta}(2s)$ is the upper β probability level of the chi-square distribution with $2s$ degrees of freedom (d.f.). Thus, given θ_a, θ_u and setting the risks α and β at the levels of probability desired or at the risks one is willing to take, then by cut and try the number of required birdstrikes, s, can be determined from the tables of percentage points of the chi-square distribution.

Alternatively, to obtain an analytic solution we consider here the Wilson-Hilferty (1931) transformation of chi-square to an approximate normal variate, i.e. obtaining for $r=2s$ d.f. the relation

$$\frac{\theta_a}{\theta_u} = \frac{r(1 - 2/(9r) + z_{1-\beta}\sqrt{2/(9r)})^3}{r(1 - 2/(9r) + z_{\alpha}\sqrt{2/(9r)})^3} \tag{6}$$

or

$$\frac{\theta_a}{\theta_u} = \frac{(1 - 1/(9s) + z_{1-\beta}\sqrt{1/(9s)})^3}{(1 - 1/(9s) + z_{\alpha}\sqrt{1/(9s)})^3} \tag{7}$$

where z_α is the lower α probability level of the standard normal distribution and $z_{1-\beta}$ is the upper β level.

With any four of the quantities θ_a, θ_u, α, β and s known, therefore, the other or fifth quantity may be found from (7). Solving (7) for s, we get

$$s = \frac{4(h-1)^2}{9(hz_\alpha-z_{1-\beta}+\sqrt{(hz_\alpha-z_{1-\beta})^2+4(h-1)^2})^2} = \frac{4}{9(\sqrt{c^2+4}-c)^2} \tag{8}$$

where

$$h = (\theta_a/\theta_u)^{1/3} \tag{9}$$

and

$$c = (z_{1-\beta} - h z_\alpha)/(h-1). \tag{10}$$

Note that the values of s in (8) are in close agreement with the respective values in Table II of the Epstein-Sobel (1953) paper when the values of (8) are rounded upward to the next integer. The following table gives comparisons for some selected values of α and β.

TABLE 1. Values of Number Birdstrikes, s, Required

θ_a/θ_u	α=0.01, E-S	β=0.05 (8)	α=0.05, E-S	β=0.05 (8)	α=0.10, E-S	β=0.05 (8)
3/2	101	98.7	67	66.3	52	51.6
2	35	34.7	23	23.0	18	17.7
5/2	21	20.3	14	13.3	11	10.2
3	15	14.4	10	9.4	8	7.2
4	10	9.4	7	6.1	5	4.6
5	8	7.2	5	4.6	4	3.5
10	4	3.9	3	2.5	2	1.8

E-S = Epstein-Sobel s (8) = s from formula (8)

3. EXAMPLE

Suppose we would like to test some fleet of airplanes to determine whether as a class they have the MFTBSB of, say, 600 flying hours or the MFTBSB of only 300 flying hours. We set a risk of 5% of rejecting the null hypothesis (MFTBSB = 600 flying hours) when true, and a risk of 10% of accepting the hypothesis (MFTBSB = 600 flying hours) when actually the true (unknown) MFTBSB is only 300 flying hours. Then our basic data would consist of the following:

$$\alpha = 0.05, \quad \beta = 0.10,$$

$$z_\alpha = -1.645, \quad z_{1-\beta} = 1.282,$$

$$\theta_a/\theta_u = 2, \quad h = 2^{1/3} = 1.2599. \tag{11}$$

From formula (8)

$$s = \frac{0.2702}{9(-3.3546+\sqrt{11.2533+0.2702})^2} = 18.7 \tag{12}$$

or take s=19, the number of birdstrikes required for the indicated protection.

The 19 birdstrikes would be distributed among the number of representative airplanes available for test and for acceptance of the true MFTBSB = 600 flying hours we must have the observed MFTBSB

$$\hat{\theta} \geq \theta\chi^2_\alpha(2s)/(2s) = 600\chi^2_\alpha(38)/38 = 393 \text{ flying hours.} \tag{13}$$

We reject the hypothesis that MFTBSB = 600 flying hours and accept the alternative hypothesis that MFTBSB = 300 flying hours if the observed $\hat{\theta}$<393 flying hours.

REFERENCES

Epstein, B. and Sobel, M. (1953). Life testing. J. Amer. Statist. Assoc., vol. 48, pp. 486-502.

Lewis, P.A.W. (1965). Some results on tests for Poisson processes. Biometrika, vol. 52, pp. 67-77.

Nechval, N.A. (1984). Theory and Methods of Adaptive Control of Stochastic Processes (in Russian). Riga: RCAEI.

Wilson, E.B. and Hilferty, M.M. (1931). The distribution of chi-square. Proc. Nat. Acad. Sciences, vol. 17, p. 684. Washington, D.C.

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DETERMINATION OF THE TOTAL FLYING TIME REQUIRED FOR TESTING THE PERFORMANCE OF A NEW ON-AIRFIELD BIRD STRIKE PREVENTION STRATEGY AGAINST THE STANDARD ONE

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ABSTRACT

Once it is acknowledged that bird strike statistics should be collected, it also becomes clear that the collection (and treatment) of such data only makes sense when it is done in a correct and detailed manner. This paper explores the methodological aspects of the following problems: (i) determination of the total flying time required for testing the performance of a new on-airfield bird strike prevention strategy against the standard one, (ii) comparison of two types of aircraft with respect to bird strike hazards. It is assumed that an observed series of collisions between aircraft and birds (bird strikes) is a realization of a Poisson process. An approximate test for the equality of the rate parameters of two Poisson processes is considered. The significance level, power and experiment length needed to achieve a specified power are compared to a previously studied approximate test. Both equal and unequal time intervals are taken into account. Numerical results show that this test, based on the variance stabilizing transformation, is superior in achieving nominal significance levels and powers over a wide range of parameter values and experiment lengths.

1. INTRODUCTION

Bird strike statistics are a main source of information on which the prevention of bird strike hazards should be based. Improvement of airworthiness, bird avoidance measurements, and on-airfield bird strike prevention strategies all are served by a sound knowledge about the circumstances under which bird strikes happen and the consequences of certain types of bird strikes. We emphasize one aspect of the problem.

Let us assume that an observed series of collisions between aircraft and birds (bird strikes) is a realization of a Poisson process. Denote by g the rate parameter of the Poisson process. Suppose two Poisson processes (corresponding to two series of bird strikes, respectively) with rate parameters g_1 and g_2 are observed for fixed flying times t_1 and t_2 respectively, and let x_1 and x_2 denote the number of outcomes (bird strikes) observed. Then X_1 and X_2 are Poisson random variables with means $a_1=g_1t_1$ and $a_2=g_2t_2$ respectively. Shiue and Bain (1982) proposed an approximate level α test of H_0: $g_1=g_2$ against H_1: $g_1<g_2$. Letting $d=t_2/t_1$ their test rejects H_0 when

$$S(1) = \frac{X_2-dX_1}{(d(X_1+X_2))^{1/2}} \geqslant z_{1-\alpha}, \tag{1}$$

where z_q is the qth quantile of the standard normal distribution. Sichel (1973) studied S(1) and the exact significance level of the associated test for the case d=1. Shiue and Bain (1982) extended the study to general d and also investigated the power of the test. Defining $r=g_2/g_1$, they used the normal approximation to S(1) to show that for given d an appropriate choice for the value of a_1 to achieve a specified power p at a fixed alternative r is

$$a_1 = ((r/d)+1)(((1+dr)/(d+r))^{1/2}z_{1-\alpha} + z_p)^2/(r-1)^2. \tag{2}$$

Thus if one has some estimate for the true value of g_1, then the required experiment lengths t_1 and t_2 can be approximated for given r, d, α and p.

Although the significance level and power of the test given by (1) and (2) are approximately correct, the true level is somewhat above the nominal for small d and below for large d. Also the power of the test tends to be larger than the nominal, indicating that the value of a_1 given by (2) may be larger than necessary. These results can be attributed to two factors. First, the convergence of S(1) to normality is somewhat slow. Second, in the expression for the approximate power used to derive (2), the variance of S(1) must be re-estimated, thus leading to further inaccuracies in the expression for a_1.

The test used here rejects H_0 when

$$S(2) = \frac{2((X_2+3/8)^{1/2}-(d(X_1+3/8))^{1/2})}{(1+d)^{1/2}} \geqslant z_{1-\alpha}. \tag{3}$$

Since variance stabilizing transformations usually accelerate the rate of convergence to normality, S(2) should converge faster than S(1) as $a=\min(a_1,a_2)$ tends to infinity. Also, because the variance of S(2) does not need to be estimated differently under H_1, the approximate power calculations should provide a more accurate expression for a_1. The use of the 3/8 in S(2) is motivated by the results in Anscombe (1948). The mean of S(2) is $2(-1+\sqrt{r})\sqrt{(a_1d)}/\sqrt{(1+d)}$ to within $O(a^{-1/2})$ whether or not the 3/8 is included. The variance of S(2), however, is improved from $1+O(a^{-1})$ to $1+O(a^{-2})$ by including the 3/8 terms. The exact power function of (3) is

$$\sum_{x_1=0}^{\infty}\ \sum_{x_2=[x_0]}^{\infty} \exp(-(a_1+a_2))a_1^{x_1}a_2^{x_2}/x_1!x_2!, \tag{4}$$

where $x_0=((d(x_1+3/8))^{1/2}+0.5z_{1-\alpha}(1+d)^{1/2})^2-3/8$ and $[x_0]$ is the smallest integer greater than or equal to x_0. An approximation to the power is given by

$$1-\Phi(z_{1-\alpha}-2(-1+\sqrt{r})\sqrt{(a_1d)}/\sqrt{(1+d)}), \tag{5}$$

where Φ is the standard normal cumulative distribution function. Setting this equal to p and solving for a_1 yields

$$a_1 = (z_{1-\alpha}+z_p)^2(1+d)/(4d(-1+\sqrt{r})^2). \tag{6}$$

Note that if one wishes to use a test of H_0': $g_1=g_2$ against H_1': $g_1\neq g_2$ of the level α, one may use a two-tailed exact test given by

$$X_2 \begin{cases} \in D, & \text{then } H_0' \\ \notin D, & \text{then } H_1' \end{cases} \tag{7}$$

where

$$D = \left\{ x_2^*:\ p_1(o,x_1,x_2^*) \leqslant (1+d)^{-1} \leqslant p_2(o,x_1,x_2^*) \right\}, \tag{8}$$

p_1 and p_2 are given by relations

$$\sum_{i=0}^{x_2^*} \binom{x_1+x_2^*}{x_2^*-i} p_1^{x_1+i}(1-p_1)^{x_2^*-i} = \alpha/2 \tag{9}$$

and

$$\sum_{i=0}^{x_1} \binom{x_1+x_2^*}{x_2^*+i} p_2^{x_1-i}(1-p_2)^{x_2^*+i} = \alpha/2, \tag{10}$$

respectively. This test has been presented in Nechval (1982) and

will not be considered further.

2. COMPARISON AND ILLUSTRATIVE EXAMPLES

Table 1 gives exact results for the two tests when $\alpha=0.05$ and $p=0.90$ for several different combinations of d and r. $\alpha(1)$ and $p(1)$ are the exact size and power of the test given by (1) and (2)

TABLE 1. Significance Level and Power Comparisons: $\alpha=0.05$, $p=0.90$

d	r	α(1)	p(1)	α(2)	p(2)
0.1	3.0	0.0591	0.9104	0.0469	0.9008
0.1	2.0	0.0574	0.9068	0.0489	0.9024
0.1	1.5	0.0535	0.9032	0.0496	0.9011
0.5	3.0	0.0538	0.9146	0.0509	0.9024
0.5	2.0	0.0524	0.9081	0.0495	0.9004
0.5	1.5	0.0515	0.9033	0.0498	0.9004
1.0	3.0	0.0494	0.9159	0.0497	0.8984
1.0	2.0	0.0494	0.9078	0.0494	0.9004
1.0	1.5	0.0498	0.9025	0.0498	0.9000
2.0	3.0	0.0408	0.9126	0.0526	0.8965
2.0	2.0	0.0466	0.9046	0.0501	0.8981
2.0	1.5	0.0485	0.9011	0.0499	0.8997
4.0	3.0	0.0383	0.9077	0.0503	0.8956
4.0	2.0	0.0441	0.9023	0.0490	0.8978
4.0	1.5	0.0472	0.9000	0.0502	0.8988

while $\alpha(2)$ and $p(2)$ are the size and power of the test given by (3) and (6). The test based on the square root transformation comes closer to the nominal level and power, particularly for the more extreme values of d. On the average the results indicate that the normal approximation to the power of the test based on $S(2)$ is more accurate than that of the test based on $S(1)$, and the resulting value for a_1 in (6) can in some cases save a considerable amount of observation time.

2.1. Determination of the Total Flying Time Required for Testing the Performance of a New On-airfield Bird Strike Prevention Strategy Against the Standard One

Suppose one wishes to test the performance of a new on-airfield bird strike prevention strategy in a fleet of $n_1=10$ aeroplanes against the standard on-airfield bird strike prevention strategy in another fleet of $n_2=20$ aeroplanes where $\alpha=0.05$, $p=0.90$ for $r=2$ and both fleets will be observed for $t_1=t_2=t$ flying hours. Here $d=n_2t_2/n_1t_1=2$ and equation (2) gives $a_1=g_1n_1t_1=19.5$. If the rate parameter g_1 of the new strategy is about 2 bird strikes per 100 flying hours then $t=19.5/(10\cdot0.02)=97.5$ flying hours per aeroplane and the total observation time will be 975 flying hours from the first fleet and 1950 hours from the second. By way of contrast equation (6) gives $a_1=18.7$ so that $t=93.5$ hours per aeroplane. The total flying times are 935 hours and 1870 hours, an overall savings of 120 flying hours. From Table 1 the level and power of the resulting test are 0.0501 and 0.8981, nearly exactly the nominal.

2.2. Comparison of Two Types of Aircraft with Respect to Bird Strike Hazards

To illustrate this point, we consider the following data taken from the paper (Bivings and Medve, 1990):

TABLE 2. Aircraft Strike Rate 1985–1989

type of aircraft	number of strikes	flying hours	strikes/ 100,000 hrs
T-44	157	199089	78.9
P-3	894	1237880	72.2
AV-8	112	159839	70.1
C-9	144	230123	62.6
A-6	382	708826	53.9
C-130	118	305000	38.7
F/A-18	223	644842	34.6
A-4/TA-4	295	855597	34.5
SH-60	76	227030	33.5
T-2	138	424817	32.5

Suppose one wishes to compare the aircraft types, say P-3 and T-44, with respect to bird strike hazards only. We reduce this problem to testing (at the specified level α) the null hypothesis H_0: $g_1=g_2$ against the alternative hypothesis H_1: $g_1<g_2$, where g_1 is the rate parameter of the Poisson process generated by collisions between the aircraft of type P-3 and birds, and g_2 is the rate parameter of the Poisson process generated by collisions between the aircraft of type T-44 and birds.

It follows from (3) that

$$S(2) = \frac{2((X_2+3/8)^{1/2}-(d(X_1+3/8))^{1/2})}{(1+d)^{1/2}} = 1.026 < z_{1-\alpha}=1.645, \tag{11}$$

where $X_1=894$, $t_1=1237880$ (for P-3), $X_2=157$, $t_2=199089$ (for T-44), $d=t_2/t_1=0.1608$, and $\alpha=0.05$. It results from (11) that there is no evidence to reject H_0 at the 5% level.

REFERENCES

Anscombe, F.J. (1948). The transformation of Poisson, binomial and negative-binomial data. Biometrika, vol. 35, pp. 246-254.
Bivings, B. and Medve, K.A. (1990). The U.S. Navy's bird aircraft strike hazard (BASH) problem 1985-1989. Proc. Bird Strike Committee Europe (BSCE), May 21st-25th, Helsinki, vol. 20, pp. 499-509.
Nechval, N.A. (1982). Modern Statistical Methods of Operations Research (in Russian). Riga: RCAEI.
Shiue, W. and Bain, L.J. (1982). Experiment size and power comparisons for two-sample Poisson tests. Appl. Statist., vol. 31, pp. 130-134.
Sichel, H.S. (1973). On a significance test for two Poisson variables. Appl. Statist., vol. 22, pp. 50-58.

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STATE OF AFFAIRS CONCERNING THE BIRDSTRIKE WARNING SYSTEM IN CENTRAL EUROPE

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SUMMARY

The Military Low-Flying Bird Strike Working Group shall develop preventive measures to minimize the bird hazard to low flying aircraft. As military aviation needs bird strike warnings covering larger areas, a dedicated observation and bird strike warning system was built up in several European countries. The paper gives a survey of the actual situation in the Netherlands, Belgium, Denmark, Germany, France and the United Kingdom and compares the bird strike warnings issued by adjoining countries in spring 1991. Future work must include improvements of the observation, reporting and warning system primarily with regard to military flight safety, but also civil aviation can benefit from the system.

1. Introduction

The procedures of bird strike warnings/BIRDTAM are mainly significant for military aircraft flying at low level. Therefore the military participants of BSCE 19 agreed to further contact on this subject besides the regular meetings of BSCE. In the meantime 7 meetings called "Bird Hazard at Low Level" were held at the German Military Geophysical Office, Traben-Trarbach/FRG, at HQ RAF Germany, Mönchengladbach/FRG, and at RNLAF Airstaff The Hague/NL, with the purpose of improving the bird strike warning system in Central Europe. The situation until 1990 was given at BSCE 20/WP 34. A survey of the current situation can be described as follows.

2. International Regulations for Bird Strike Warnings

The NATO countries agreed on the usefulness and importance of bird strike warnings covering larger areas. The format is laid down within the NATO by the standardization agreement STANAG 3879 FS-Birdstrike Risk/Warning Procedures (Europe). The ratification of the STANAG does not mean that all these countries are able to issue bird strike warnings, but they agree in principle to the content and format.

Bird strike warnings are based on real observations of bird migration mostly by radar, but also visually by pilots or ground staff. Visual detection as well as the identification of bird echoes on the radar screen, and the determination of the bird intensity are difficult, if standardized procedures and calibrated data are missing. Therefore two editorial changes of the STANAG concerning the calibration of warnings and the exponential structure of the intensity scale were accepted, whereas the question at which intensity the Air Forces should stop flying could not be answered on the existing data base.

3. Actual Survey of the Bird Strike Warning System in Several European Countries

The existing observation system of bird movements is unequal in several European countries. Only Belgium, Denmark, the Netherlands, and Germany observe regularly migratory movements of birds by radar, and issue bird strike warnings/BIRDTAM also to foreign countries. These observations are not calibrated with each other due to different equipments and techniques of identification. Therefore differences in bird intensities often occur at the borders of the warning areas covered by one country. The essentials of the system were outlined in BSCE 19/WP6 and BSCE 20/WP34. The current situation can be summarized as follows.

In the Netherlands the electronic counting system ROBIN (see BSCE 19/WP 40 and BSCE 20/WP 36) is taken into operational use.

ROBIN consists of two cooperating systems: a registration system located near the radar and a presentation system which can be separated geographically. An interface between ROBIN and other radar types is in development. Then ROBIN can be implemented also at a smaller (e.g. ATC-)radar as planned for the South of Holland and in foreign countries (IL, UK). The results of ROBIN are influenced by the flight altitude of birds and the distance from the radar site. Therefore the best results would be expected by a dedicated pencil-beam bird radar which would be much cheaper than the existing radar systems, but the development of such a system would take several years.

The operational version of the ROBIN system proved to be very worthwhile in the detection and assessment of bird movements. During one migration period 10 - 15 days with bird intensities 7 and 8 were noted in accordance with the experience of other countries. The results are issued daily by the Air Staff, section Ornithology, in the form of an integrated bird migration report covering the Netherlands, Belgium, Luxemburg, and parts of Germany and France, and indicating per GEOREF the bird intensity and altitude of the bird strike danger.

In Belgium the electronic counting system BOSS (see BSCE 17/WP 37, and BSCE 18/WP 16) is implemented at Belga Radar. From 1985 to 1990 bird detection in Belgian FIR was performed by BOSS 1985. During 1990 studies were started at the military radarstation Semmerzake to develop a new system for bird observation, using a standard PC and making BOSS fully independant on any radar configuration. During spring migration 1991 the system was tested and calibrated. A high amount of plot files from different radar sources were recorded and processed by the system into track files with the highest number of tracks taken into account to give the bird intensity for each GEOREF.

By comparing the obtained results with data of BOSS 85 and also by taking into consideration BIRDTAM issued by RNLAF and GAF, tracking parameters were adapted and the algorithm to calculate the bird intensity was adjusted. After the analysis of the selected radarfiles

a plotter can produce a map with GEOREF of the Belgian FIR with the radars used showing each in their particular colour, their observed tracks, and in each GEOREF the bird intensity. Actual height indication was available from the two air defense radar stations involved in the system.

In a further step the bird info from airfield radars (RAPCON) can possibly be included into the program.

In Denmark the electronic counting system FAUST (see BSCE 8/WP 8-2) is still in use. Unfortunately bird intensities were often missing due to technical reasons. the intensities reported did not always correspond to the Belgian and Dutch messages due to technical and ornithological reasons, for in Denmark not only long term migratory movements but also local migratory patterns are recorded by radar.

In the Federal Republic of Germany all attempts to establish electronic counting procedures at the air defense stations have been failed 'till now. The photographic registration system is still in use (see BSCE 18/ WP 5) at 10 air defense radar stations. The system is complemented by several ATC-airfield radars, two weather radars, and visual observers, mostly belonging to the German Military Geophysical Service. The main problem of these observations is the fact that ATC-radars operate within a smaller range than air defense radar stations, and record mostly bird movements at lower altitudes. Therefore the bird intensities reported do not correspond to each other. Furthermore the conversion of visual observations into bird intensities can only be an estimation. The visual observations refer only to larger birds as waterfowl, crane, and storks, and are used as an indicator for medium or heavy bird migration. These limitations are the reason that visual observations can only supplement the radar observation, but cannot take the place of it.

All observation messages are evaluated in the German Military Geophysical Office (GMGO) according to standing procedures, and converted into bird strike warnings/BIRDTAM, if necessary. For the area of East Germany observations of bird movements are still missing. The radar equipments will be tested for this purpose in 1992, and visual observations will be performed in the future mostly by the civil Weather Service, as the number of military airfields will be relatively small.

In France the detection of migrating birds is possible by airfield radars (ALADIN) and CENTAUR-Radars, as well as by visual observations which will be facilitated by a booklet recently published by the Technical Services of the Air Navigation. When bird presence is considered as dangerous, bird movement forecasts (RPMO), respectively messages of local bird observations (ROPOM), are sent to the Operation Center of the Air Defense which spreads the message as a BIRDTAM to each air base.

In the United Kingdom a dedicated warning system with regard to migratory movements of birds did not seem to be necessary, as the UK is situated at the end of the European migration routes. But the increasing number of LL flights, and the costs of bird strikes require a new assessment of the situation. In spring 1991 a program was performed with the aim to determine to what extent birds can be observed by the existing radar equipment. 26 airfield radars belonging to 4 radar types were included into the observation program, and the different radars could be assigned to 7 geographical groups. The range for the detection of birds was between 5 and 25 NM according to the different radar types. The reports contain date, time, location, flight direction, and bird intensity subjectively judged (low/medium/ high) in relation to the number and size of radar echoes.

As LL flights were not restricted during the observation period days with high flight activity of birds, and bird strikes could be compared very well. In March the two graphs did correspond outstandingly proving the close connection between migratory movements, and bird hazard to aircraft. whereas in April - June such a correspondence was missing, mostly due to local bird movements detected by radar.

The positive results of the radar observation program makes it possible to include in the near future bird hazard information in the Low Flying Information System ALFIN used by civil and military aircraft.

4. Comparison of Bird Strike Warnings Issued by Adjoining Countries

Birdtam/Birdstrike Warnings are regularly distributed by Belgium and Denmark, The Netherlands and Germany. Except for Germany, all warnings

are based directly on radar observations. A comparison of warnings issued by adjoining countries can prove the effectiveness of the national systems and demonstrate the problems.

From January to June 1991 GMGO issued 182 BIRDTAM and received 218 Bird Warning Messages from NL, 116 Bird Risk Warnings from DK and 19 BIRDTAM from BE. The distribution of bird intensities over this period showed remarkable differences between those four countries (see Table 1). In Belgium the most frequent intensity in the warnings was 7, in Denmark 6, in Germany 5, and in the Netherlands there was a continuous decrease from below 5 to 8, which should be expected theoretically (see Table 2). In Belgium the low number of warnings, in Denmark the high amount of warnings with intensities not measured, and in Germany the high amount of BIRDTAM based on local radars and visual observations, seem to cause these differences.

Nevertheless the busiest days of bird migration were recognized very well by Belgium, Germany, and the Netherlands, differing only by one step on the intensity scale (see Fig. 1). The results show that in spite of the different observation systems the results correspond to some extent if all observation stations involved in the system are contributing continuously information to the system.

5. Future Work

According to BSCE 20/ WP 34 the bird strike warning system in Central Europe can only be improved significantly by

- continuous observation of bird movements based on radar, and providing calibrated data of bird intensities with respect to distinct areas and altitudes,
- quick exchange of data, respectively warnings between adjoining countries,
- standing procedures with respect to flight restrictions due to known bird strike danger.

These requirements are especially important for military flight safety. But also civil aviation can make use of the bird strike warnings/BIRDTAM with regard to the vicinity of airports. As a first step the German Federal Office of Air Traffic Control will convert the German BIRDTAM of intensities 7 - 8 into bird strike risk warnings with regard to Flight Information Regions (FIR) and aerodromes as part of the NOTAM data base.

In the progress reports of the last meetings of the expert group "Bird Hazard at Low Level" the following recommendations were addressed to military authorities:

1) that nations pursue the aim of calibrated electronic assessment of radar data concerning the low level bird hazard
2) that nations evaluate the capability of currently deployed, and the future or projected radar systems to fulfill the aim of electronic assessment of such radar data
3) that nations investigate the possibility of contributing to a dedicated multi-national system for the detection, reporting, and the dissemination of birdstrike hazard warnings
4) that the national air staff consider/reconsider, how the bird strike warnings/BIRDTAM transmitted via ATC- and Wx-network can be obtained, and be upgraded to a comprehensive message
5) that nations note, that the most effective equipment for bird detection and warning is considered to be a small dedicated 3 D radar system
6) that nations explore the operational need of bird strike warning in the vicinity of the air bases
7) that nations support the proposal to MAS that the latest version of the European military bird strike reporting form should be added to STANAG 3879 FS as an Annex.

Money spent for these purposes would improve considerably the flight safety without hindering too much the Flying Units in their operational tasks.

Table 1:

Number of Bird Warning Messages January - June 1991

	Jan/Feb '91	Mar/Apr '91	May/Jun '91
BELGIUM	0	19	0
DENMARK	46	23	47
NETHERLANDS	56	115	47
GERMANY	28	120	34

Table 2:

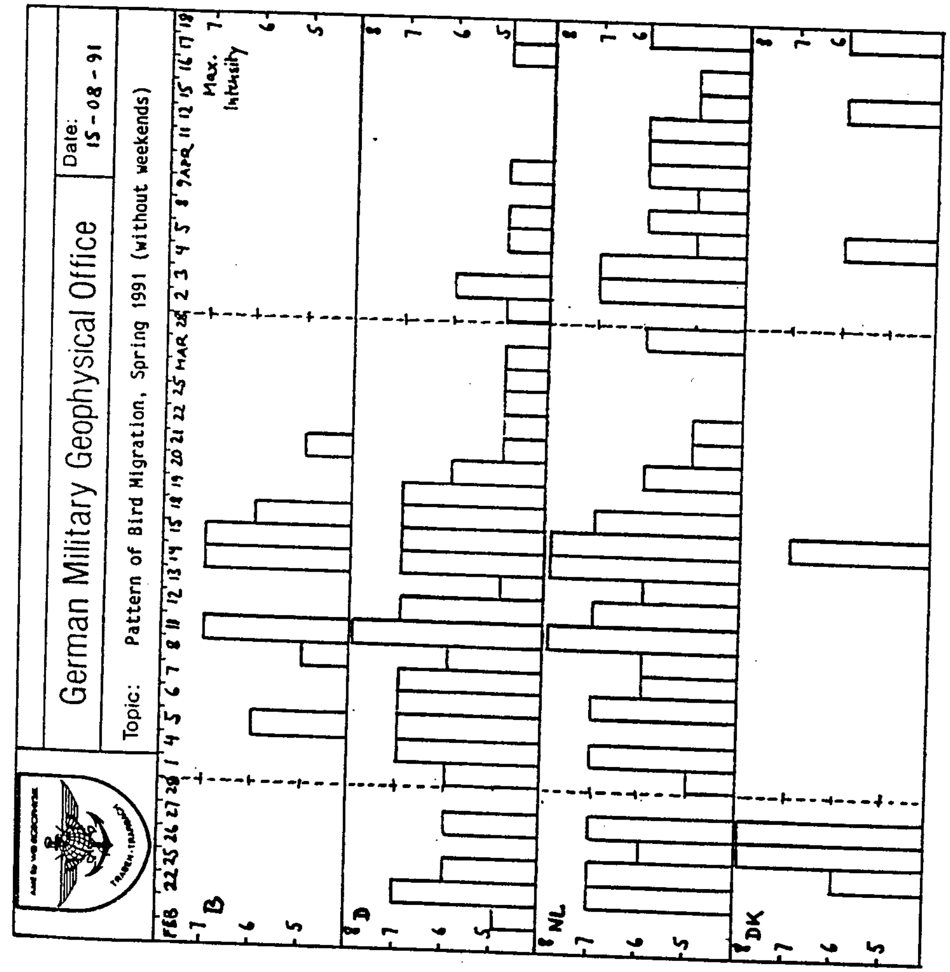
Maximum Intensities of Bird Warning Messages January - June 1991

Max. Intensities	< 5	5	6	7	8	n.m.
BELGIUM	-	4	5	9	-	-
DENMARK	-	8	49	2	2	48
NETHERLANDS	95	52	49	19	6	-
GERMANY	39	79	29	32	3	-

n.m. = not measured

Figure 1:

Pattern of Bird Migration in Central Europe, Spring 1991, Based on Maximum Intensities of Bird Warning Messages



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COLLECTING EFFORTS AND IDENTIFICATION STANDARDS IN RELATION TO BIRD STRIKE STATISTICS

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ABSTRACT

Different methods of feather identification are discussed and evaluated, such as macroscopical comparison with bird skins, microscopical examination of feather structure, and biochemical analysis of feather proteins. The results of the microscopical investigation of feathers as applied to bird strike analysis in the Netherlands are evaluated. It is demonstrated in which ways accurate identification procedures may affect bird strike statistics. The main conclusion is that proper identification of bird remains is fundamental and essential to bird strike statistics. Aviation authorities should direct their efforts towards the improvement of the general reporting and collecting standard, whereas biologists should optimize and standardize their identification methods, advertise the possibilities of different identification techniques, and make their expertise available.

Key Words: Collecting of bird remains, identification methods, reliability of bird strike statistics.

INTRODUCTION

One of the first steps in reducing the risk collisions between birds and aircraft is establishing which species are most likely to cause an accident. Only when a detailed insight regarding the species most frequently involved in bird strikes has been obtained, the most adequate preventive measures may be taken, in both bird control and aircraft design. Especially during the last decade, the notion that an adequate assessment of this problem by keeping accurate bird strike statistics is indispensable for taking the most appropriate preventive measures, has become generally accepted.

REPORTING AND COLLECTING

Internationally, bird strike reporting systems have been set up to get an insight into the bird hazard. However, due to different factors, in most data sets the number of cases in which the bird has been identified is low in comparison to the total number of strikes. In some analyses, the number of unidentified birds is given (Table 1), but in others these are fully ignored. In either case, both conclusions and preventive measures are often based on an extremely limited number of cases and possibly biased statistics.

TABLE 1. Percentage of unidentified birds in bird strike statistics*

source, year, reference	N	unknown
Civil, world-wide, 1972-1975 (Thorpe 1977)	3806	48%
Civil, world-wide, 1976-1980 (Thorpe 1984)	7318	50%
Civil, world-wide, 1981-1985 (Thorpe 1990)	7544	42%
Civil, world-wide, 1989 (ICAO 1991)	4777	36%
Civil (engine ingestions), world-wide, 1981-1983 (Frings 1984)	638	50%
Civil, USA, 1978 (Harrison 1979)	788	20%
Civil, Australia, 1982 (Davidson 1984)	552	27%
Civil, Australia, 1983 (Davidson 1985)	430	21%
Military, northwestern Europe, 1981 (Leeming 1984a)	1271	64%
Military, northwestern Europe, 1982 (Leeming 1984b)	1489	62%

The total number of unknown birds involved in collisions with aircraft may be divided into four categories.

1) The first concerns strikes that occur unnoticed. No estimation exists regarding the percentage of cases that is simply not noticed, neither by pilots at the moment of impact nor by ground personnel during post-flight inspections.

* These data-sets have been selected as examples to illustrate the problem regarding the reporting of strikes and the collecting and identification of remains. It is by no means the author's intention to criticize individual workers active in the field of bird strike prevention.

2) The second category is due to strikes that are not reported. Several factors may account for defective reporting and hence for unreliable or biased statistics (e.g., Blokpoel 1976, Lind 1978). Bird strike reports are delivered by pilots, groundstaff, Bird Control Units, or engineers, and the quality depends on the dedication and ornithological knowledge of these people. Reporting standards vary considerably among countries, airlines, and airports, and this fact alone raises the question of how meaningful bird strike statistics are (e.g., Thomas 1988), in particular when data from different organizations or countries are combined or compared. A study to assess the size of this category indicated that 67% of the bird strikes had not been reported (Bivings & Medve 1990); others have estimated this number to be as high as 80 to 85% (Lind 1978, Harrison 1979).

3) The third category is the number of bird remains that are not collected. The importance of retaining bird remains may not be fully understood by everyone who is in the position to collect them for identification and motivation to submit remains for identification varies from person to person. Furthermore, some organizations are interested in the exact identification of the species only if damage has been done to aircraft. Thus, large birds which caused spectacular damage are more frequently collected than small remains which often cause negligible damage.

4) Bird remains that cannot be identified constitute the fourth group. Identification standards differ greatly among countries. In some countries the birds involved are identified by airfield personnel, in others identification services are provided by professional biologists who analyse bird remains. In many data sets (e.g., Thorpe 1977, 1984, 1990, Melville 1980), the identification standard ranged from the examination of remains by trained ornithologists to the fleeting glance of a pilot. Consequently, the statistics may be biased strongly by the presence of large and easily recognizable species, which, however, do not necessarily constitute the highest risk.

Although these categories are interrelated, their respective contribution to the total number of 'unknowns' probably varies among countries and organizations. In any case it is evident that the reliability of bird strike statistics can only be enhanced by the coordination of activities in two different domains, aviation and biological research. Aviation authorities should direct their efforts towards the improvement of the general reporting and collecting standard. This may be achieved by several measures, such as the obligatory use of standard reporting forms forcing reporters to pay attention to the relevant details, the establishment of Bird Control Units at airfields (Anon. 1977, Buurma 1977) or the centralization of bird strike reports (e.g., Dekker & Buurma 1990). Programs emphasizing the importance of collecting and identification can be highly effective. The success of such a campaign was demonstrated in Denmark where the percentage of unidentified birds decreased from 56% to 36% in a five-year period (Joensen 1978). It may be evident that, if bird strike statistics are to be standardized internationally, much work remains to be done, especially in the field of information and motivation of pilots,

airfield personnel, and engineers. Biologists should optimize and standardize their identification methods, advertise the possibilities of different identification techniques, and make their expertise available. One possibility to achieve international standardization of identification methods is centralizing identification expertise (e.g., Brom & Wattel 1990). The only way to exclude unreliable data from the statistics is disregarding identifications done by non-biologists.

METHODS FOR IDENTIFYING BIRD REMAINS

In recent years, the search for diagnostic characters that might be used for identification purposes has been intensified (Brom 1991, and references therein). Apart from preliminary biochemical studies of blood and flesh remains (e.g., de Bont *et al.* 1986), attention has been focused on the identification of feathers and feather fragments. The most important reason for this choice is a practical one: When blood or flesh remains are available for examination, usually feathers are as well, but conversely, feathers are often found without any trace of blood or flesh.

Macroscopical comparison of feathers

The traditionally used and most straightforward way of feather identification is that of comparing unknown feathers with a reference collection. Evidently, the results strongly depend on the condition of the bird remains. Provided that the samples are large enough and contain characteristic feathers, identification rates are high at all taxonomic levels (Table 2).

TABLE 2. Identification results obtained by macroscopical examination (number of bird remains is set at 100%; small samples were omitted from these results).

country/organisation/period	N	identification results in % unknown	order	family	genus	species
Estonia 1951-1988 (Shergalin 1990)	335	0	100	94	65	61
Netherlands 1960-1977 (Brom 1988)	119	0	100	92	88	74
Australia 1982 (Davidson 1984)	331	0	100	96	56	33
Australia 1983 (Davidson 1985)	392	0	100	100	44	36

The main disadvantage of this method is the fact that minute remains cannot be identified macroscopically, and, hence, that a large proportion of bird remains are being discarded, either during collecting or identification.

The advantage of the macroscopical method is that in many cases a distinction between age classes can be made, which is necessary to enable establishing whether juvenile birds are more likely to cause an accident than adults. Neither microscopical nor

biochemical studies have yielded diagnostic age characters, thus confining information on the bird's age exclusively to macroscopical criteria. It should be realized that for some species hardly any differences in plumage exist between juvenile and older birds, whereas in others these differences are quite pronounced, at least during certain periods of the year. Differences in the availability of macroscopical age characters between species are clearly reflected by the ages assignment in Table 3 (compare e.g., skylark with herring gull).

TABLE 3. Age classes of 15 bird species most frequently encountered in feather remains from bird strikes (multiple strikes included), LM examination combined with macroscopical comparisons, 1960-1990.

	species		N	juvenile/ immature	adult	age unknown
1.	swift	*Apus apus*	309	1%	38%	61%
2.	lapwing	*Vanellus vanellus*	138	11%	10%	79%
3.	black-headed gull	*Larus ridibundus*	75	39%	43%	18%
4.	buzzard	*Buteo buteo*	63	2%	6%	92%
5.	skylark	*Alauda arvensis*	62	0%	2%	98%
6.	swallow	*Hirundo rustica*	58	14%	7%	79%
7.	rock dove/feral dove	*Columba livia*	44	7%	0%	93%
8.	wood pigeon	*Columba palumbus*	43	2%	2%	96%
9.	chaffinch	*Fringilla coelebs*	37	8%	5%	87%
10.	common gull	*Larus canus*	35	26%	60%	14%
11.	starling	*Sturnus vulgaris*	33	33%	3%	64%
12.	herring gull	*Larus argentatus*	28	36%	64%	0%
13.	house martin	*Delichon urbica*	25	4%	8%	88%
14.	kestrel	*Falco tinnunculus*	19	21%	21%	58%
15.	mallard	*Anas platyrhynchos*	19	0%	26%	74%

Microscopic identification in combination with macroscopical comparisons

Although the search for new diagnostic characters still continues (e.g., Dyck 1990, Perremans 1990, Frank & Brom: this meeting), downy barbs have been found to exhibit the most appropriate feather structures for identification purposes (Brom 1991). The observation that downy barbs are most frequently found in engines or on aircraft, is of equal importance to the decision that identification procedures should be based on the microscopical study of their structures. When pennaceous feathers are available for examination, downy barbs are usually present as well, but conversely, downy remains are often found without any trace of pennaceous structures. Apparently, downy barbs adhere more easily to aircraft than pennaceous ones.

The results that can be obtained with the microscopic investigation of feather remains in combination with macroscopical comparisons are illustrated by the evaluation of the results in the Netherlands in the period 1960-1990. At the Zoological Museum Amsterdam (ZMA), 83 species of birds* have been identified in this period (nine of which originated from collisions with civil aircraft outside Europe), belonging to 28 families and 12 orders (Table 5). Although in every case (N= 2181) bird strikes could be confirmed by the presence of feather material in the samples, it was impossible to give a more accurate identification than 'Bird' in 4% (N= 82) of all cases. The results are given in Table 4 and Fig. 1.

TABLE 4. Identification results classified per taxon, LM examination combined with macroscopical comparisons, 1960-1990.

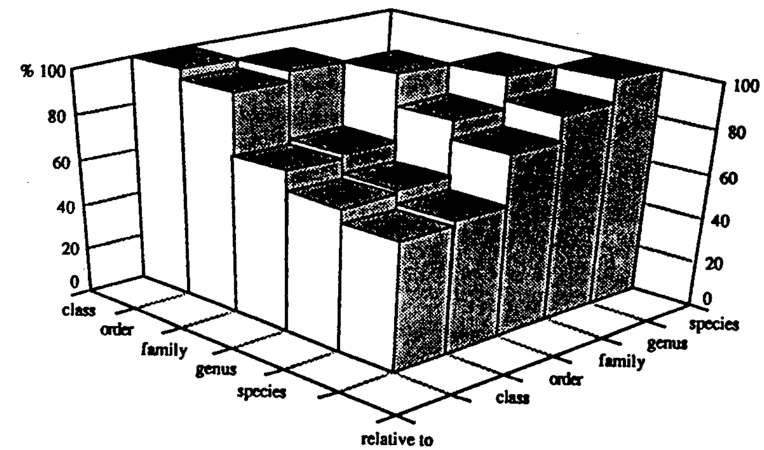
taxon	N	%	%	%	%
class	2181	100			
order	2099	96	100		
family	1517	70	72	100	
genus	1320	61	63	87	100
species	1194	55	57	79	90

When the results of the macroscopical identification (Table 2) are compared with those of Table 4, it would appear that the microscopic method does not lead to an increase of identification rates at the taxonomic categories below the order level (Table 4, Fig. 1). However, in Table 4 minuscule feather remains have also been included, whereas these have probably been discarded in macroscopical examinations.
The species most frequently represented is the swift (Table 3), which accounts for 14% of the total number of investigated bird strikes in the period 1960-1990. Although this bird is only present in northwestern Europe from mid April to early September (the earliest collision was on 24 April, the latest on 5 September, but 91% of all strikes occurred in the period May-July), it accounts for 26% of all identifications to species level. In the identifications to family level, the Apodidae also score highest with 20%, followed by the gulls and terns (Laridae/Sternidae) with 18%. At the order level, the Passeriformes score highest with 41%, followed by the Charadriiformes with 25%.

These results are in strong contrast with other analyses. In many comparable data sets, collected either from the same geographical area or world-wide, both songbirds and swifts are represented by insignificantly small numbers. In the analysis of engine ingestions (N= 638) that occurred world-wide in the period 1981-1983, the swift was found only once (Frings 1984) whereas in the bird strikes reported to civil aircraft in 1989

* Included are only those remains that have been received by the ZMA whereas approximately 2% of the total number of remains is the result of bird strikes with civil aircraft. Therefore the data presented in the Tables 3-5 should not be interpreted as an accurate picture of the bird strike statistics of the Royal Netherlands Air Force.

FIGURE 1. Graphic representation of the identification results given in Table 4.



(ICAO 1991), it formed less than 1% of the total number (N= 4777) of reported cases. In the former analysis, a similar discrepancy may be observed at the level of orders: Passeriforms score only 7% of the identified remains (N= 322) which is 4% of the total number of remains (Frings 1984). Theoretically, the high number of strikes with swifts and songbirds in north-western Europe might be caused by a higher population density of these birds in this region than in other parts of the world. However, comparisons of the periods 1960-1977 and 1978-1990 have clearly demonstrated that these higher numbers are the result of the introduction of the microscopic examination of feathers in combination with a more conscientious search for even the smallest feather fragments by airfield personnel. From 1978 on, a drastic shift towards smaller birds took place. At the order level, the detection of songbirds increased from 9% in 1960-1977 to 41% in 1978-1990. At species level, swifts increased from 11% in 1960-1977 to 26% in 1978-1990. A similar trend has been observed in the United Kingdom where incidents involving species weighing 150 g or less increased from 9% in 1968 to 30% in 1976 (Rochard & Horton 1977). It may therefore safely be assumed that small birds are under-represented in bird strike statistics (see also Milsom 1990), and that microscopic examination of feather remains detects taxa that remain hidden in the high percentage of 'unknowns' in many data sets which are based exclusively on macroscopical examinations (Table 1).

The main disadvantage of the microscopical method is that it usually allows identification to the higher taxonomic categories only. Although some authors claim to have worked successfully at the species level, the differences between closely related groups and, especially, between species are so small that constructing a key at this level is not possible.

The identification rates vary considerably among different orders (Table 5), due to taxonomic and biogeographical reasons. Therefore, the identification results as classified per taxonomic category (Table 4, Fig. 1) should not be interpreted too rigidly. In many cases, once the order to which the bird belongs has been established, this leads to the identification at a lower taxonomical level, either because the order is monotypic or because only a single representative of that order is to be expected in a certain region. Due to the characteristic feather structure of the Apodiformes, the swift can easily be identified, even in the smallest remains. In other orders, in particular that of the songbirds, the determination of 'Passeriformes' still leaves open many potential species in several families and genera. This implies that the microscopic method may also introduce a bias in bird strike statistics, in particular in favour of taxa which possess characteristic feather structures.

TABLE 5. Identification results within the orders most frequently encountered, LM examination combined with macroscopical comparisons, 1960-1990.

	Accipitri		Anseri		Apodi		Charadrii		Columbi		Falconi		Galli		Passeri	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
order	80	100	59	100	309	100	523	100	201	100	28	100	24	100	859	100
family	80	100	59	100	309	100	443	85	201	100	28	100	24	100	357	42
genus	69	86	35	59	309	100	384	73	128	63	28	100	24	100	330	38
species	69	86	33	56	308	99	323	62	94	46	24	86	24	100	306	36

Biochemical analysis of feather remains

In recent days, electrophoresis has become a reliable and repeatable procedure for the identification of feather remnants from any source (Ouellet & van Zyll de Jong 1990). Within the family Laridae, a group of birds frequently involved in bird strikes, seven species of gulls could be distinguished., whereas little individual, sexual, or age variation was found. Thus, it seems that keratin electrophoresis is the only technique presently available that allows identification to species level. This method may be applied once the identification of downy barbs has led to the group to which the bird belonged. Since biochemical techniques are more time-consuming than microscopical investigations, they should be applied preferably in special cases, such as the investigations of accidents or the analysis of a notoriously problematic group.

CONCLUSION

Identification methods which may be applied in bird strike analysis are:
a) macroscopical comparisons of complete feathers to reference collections,
b) microscopic examinations of structures in different parts of the feather,
c) biochemical investigations of feather proteins.

For routine purposes the most effective method at present is the study of the microstructure of downy barbs with light- and scanning electron microscopy combined with the use of a reference collection of bird skins. The advantages of the identification by microscopic examination of downy barbs are five-fold:

1) Most feathers can be easily assigned to the order or family to which the bird belongs. Hence, in subsequent macroscopical examinations only a limited number of taxa needs to be considered and the identification process is therefore much less time-consuming than in the past.

2) From the microscopical investigation of scrapings collected from engines it can always be concluded unambiguously whether feather remains are present. In this way, defective engines may be divided into those owing to either bird strikes or mechanical failures.

3) Even minute feather remains usually provide information at least to order level.

4) For bird strike analysis it is very useful that in several groups of birds a tendency exists that larger species have fewer nodes per mm of barbule than smaller birds (Brom 1991). In this way an indication of the weight of the bird may be obtained without exactly knowing the actual species involved. Since weight is a key factor in the analysis of bird strikes, this is of utter importance. For example, within the Passeriformes, crows can always be distinguished from small songbirds. In a similar way, a distinction can be made between ducks, geese, and swans in the family Anatidae (Horton 1990).

5) Provided that biologists clearly indicate the possibilities of their identification expertise and demonstrate that small remains should be treated as seriously as easily recognizable ones, the microscopic identification method may have a positive feed-back on the collecting efforts by airfield personnel. The introduction of microscopic methods may lead to a more conscientious search for these small feather fragments by airfield personnel, and, hence, to an increase of the number of collected remains.

The need for internationally comparable bird strike statistics is obvious, but standardization of identification results can only be achieved if the need for cooperation has been made clear to aviation authorities and professional biologists.

REFERENCES

Anon. 1977. *Bird Control Units in the RAF.* London: Ministry of Defence, United Kingdom Bird Impact Research and Development Committee.

Bivings, B. & Medve, K.A. 1990. The U.S. Navy's bird aircraft strike hazard (BASH) problem. *BSCE 20 (Helsinki):* 499-509.

Blokpoel, H. 1976. *Bird Hazards to Aircraft.* Ministry of Supply and Services, Canada.

Bont, A. de, Boomans, J.F., de Raeve, P., Hoet, E. & Verachtert, B. 1986. Strategies for the identification of bird remains from birdstrikes. Survey and advanced approach by analysis of tissues. *BSCE 18 (Copenhagen):* 113-122.

Brom, T.G. 1988. The analysis of feather remains: evaluation and perspectives. *BSCE 19 (Madrid):* 341-356.

Brom, T.G. 1991. *The Diagnostic and Phylogenetic Significance of Feather Structures.* Thesis, University of Amsterdam: 279 pp.

Brom, T.G. & Wattel, J. 1990. Proposal for the establishment of a European Centre for the identification of bird remains. *BSCE 20 (Helsinki):* 223-234.

Buurma, L.S. 1977. Establishment of Bird Control Units at 6 Dutch air bases. *BSCE 12 (Paris), WP* 27: 1-4.

Davidson, P.M. 1984. Birdstrikes to civil aircraft in Australia during 1982. *Department of Aviation, Bird Hazard Investigation Report* 3: 1-21.

Davidson, P.M. 1985. Birdstrikes to civil aircraft in Australia during 1983. *Department of Aviation, Bird Hazard Investigation Report* 4: 1-21.

Dekker, A. & Buurma, L.S. 1990. Towards a European database of military bird strikes. *BSCE 20 (Helsinki):* 105-128.

Dyck, J. 1990. The ways in which feather colours are produced and their potential for identification of feather remains. *BSCE 20 (Helsinki):* 543-548.

Frank, U. & Brom, T.G. 1992. The diagnostic significance of thickened and pronged hamuli in feathers. *(this meeting).*

Frings, G. 1984. *A Study of Bird Ingestions into Large High Bypass Ratio Turbine Aircraft Engines.* Springfield: National Techn. Inform. Service.

Harrison, M.J. 1979. Aircraft bird strikes. Summary and analysis calendar year 1978. *BSCE 14 (The Hague), WP* 6B: 26 pp.

Horton, N. 1990. Distinguishing between ducks, geese and swans by means of feather micro-biometrics. *BSCE 20 (Helsinki):* 327-337.

ICAO 1991. *IBIS World Bird Strike Statistics for 1989.* Montreal.

Joensen, A.H. 1978. *Bird Species involved in Bird-strikes with Military Aircraft in Denmark, 1968-77.* Game Biol. Station Kalø Rønde: 18 pp.

Leeming, G.H. 1984a. Military aircraft birdstrike analysis 1981. *BSCE 17 (Rome):* 147-153.

Leeming, G.H. 1984b. Military aircraft bird strike analysis 1982. *BSCE 17 (Rome):* 154-163.

Lind, H. 1978. The identification of bird remains as part of the bird strike reporting procedure. *BSCE 13 (Bern), WP* 3: 1-5.

Melville, D. 1980. *Birdstrike Data from Kai Tak Airport Hong Kong 1974-1979.* Mimeographed report, Agricult. & Fish. Dept. Hong Kong: 1-57.

Milsom, T. 1990. The use of birdstrike statistics to monitor the hazard and evaluate risk on UK civil aerodromes. *BSCE 20 (Helsinki):* 303-320.

Ouellet, H. & van Zyll de Jong, S.A. 1990. Feather identification by means of keratin protein electrophoresis. *BSCE 20 (Helsinki):* 53-71.

Perremans, K. 1990. External surface structures of rachis, rami and rachidial barbules of feathers and their potential for determination purposes. *BSCE 20 (Helsinki):* 21-30.

Rochard, J.B.A. & Horton, N. 1977. Birds killed by aircraft in the United Kingdom, 1966-76. *World Conference on Bird Hazards to Aircraft (Paris), WP* 4: 1-17.

Shergalin, J.E. 1990. Bird strikes analysis in Estonia 1951-1988. *BSCE 20 (Helsinki):* 183-199.

Thomas, C. 1988. How meaningful are bird strike statistics. *BSCE 19 (Madrid):* 557-566.

Thorpe, J. 1977. Analysis of bird strikes reported by European airlines 1972 to 1975. *World Conference on Bird Hazards (Paris), WP* 6: 33 pp.

Thorpe, J. 1984. Analysis of bird strikes reported by European airlines 1976-1980. *BSCE 17 (Rome):* 60-87.

Thorpe, J. 1990. Analysis of bird strikes reported by European airlines 1981-1985. *BSCE 20 (Helsinki):* 263-294.

WP 20

Paper on the performance of the bird control service on French airports

(Presented by MM. A. BERMAN, J.L. BRIOT and A. EUDOT)

1. APPLICABLE REGULATION

The decree of 24th July 1989 defined the organization of the bird control service on French civil aerodromes, as well as the responsabilities incumbent on the State, on aerodrome administrators and on pilots or their representatives, respectively.

2. MAIN ELEMENTS OF THE DECREE

In the terms of the decree of 24th July, 1989

(I) the State Departments are responsible for:

- defining and monotoring the initial standardization of airport environment (type of crops, grass mowing, etc...),
- determining the minimum financial means to be put at the disposal of the various aerodromes and subsequently defining the equipment and human organization to be implemented,
- defining the standards for material and equipment to be used for the bird control service,
- initial acquisition of the fore-mentionned material and equipment,
- training of staff responsible for bird hazards prevention on airports,
- preparation of contractual documents (conventions) linking the state departments and aerodrome administrators,
- monitoring of bird control service performance and, when necessary, providing assistance to aerodromes.

(II) Aerodrome administrators are responsible for:

- maintening the material and equipment assigned to the bird control service,

- assigning sufficient personnel (in most cases those from the aerodrome based fire protection unit) to the bird hazard prevention service.

(III) Pilots or their representatives are responsible for:

- reporting all data or observed situations in connection with bird hazards likely to concern state departments or aerodrome administrators.

3. TRANSITION PERIOD

The decree of 24th of July, 1989, designated a period of two years for the state departments and aerodrome administrators to achieve conformity with statutory documents.

4. PRESENT SITUATION (on 01.09.1991)

At the end of the transition period, the situation is as follows:

METROPOLITAN FRANCE	:	95 aerodromes meet standards,
OVERSEAS DEPARTMENTS	:	5 aerodromes meet standards.

The situation , according to the minimum financial means available, is as follows:

GROUP B:54 aerodromes (4 of which are in overseas departments)
GROUP C:35 aerodromes (1 of which is in an overseas department)
GROUP D: 7 aerodromes
GROUP E: 4 aerodromes

Note: A temporary interruption of birds hazards prevention service activities will be announced through an aeronautical publication addressed to pilots (NOTAM).

5. INTERIM EVALUATION

The interim evaluation, carried out after the effective implementation of the bird control service, is particularly encouraging:

1) 100 aerodromes have EFFECTIVELY been brought to statutory standards,

2) State departments and aerodrome administrators in general have been made aware of the importance of the bird hazards prevention service as a significant factor in aerodrome safety,

3) reports on the real birdstrike hazards situation on french airports have increased by about 30% in two years,

4) the number of significant collisions with birds decreased by 50% during the year following the introduction of the service on aerodromes where it did not previously exist.

It should also be noticed that bird control had already been implemented on some aerodromes before 1989 in advance of the new national regulation

6. PROSPECT FOR THE 1992-1993 PERIOD

- Aerodrome classification will be reviewed according to experience gained and, if necessary, modifications will be implemented,

- some additional aerodromes, in metropolitan France as well as in overseas departments, will be brought to standard,

- permanent training will be ensured by state departments taking into account the movement of staff responsible for the bird control on aerodromes.

7. PROPOSAL

At the 21st meeting of the BSCE, French experts suggest that it would be useful to set up a working group at the European level in order to improve and coordinate the harmonious organization of bird control services on aerodromes based on experiences gained in different states.

8. APPENDICES

The following documents are appended:

Appendix A aerodrome classification summary

Appendix B list of classified aerodromes in metropolitan France

Appendix C statistical data on the actual situation on aerodromes concerning birds hazards.

Appendix A

MINIMUM EQUIPMENT REQUIREMENTS

LEVEL OF MEANS	PERSONNEL	MOBILE RESOURCES				FIXED RESOURCES *
		VEHICLE	DISTRESS CALL GENERATOR	PYROTECHNIC RESOURCES	HUNTING	
E	1 LC 1 OP1 all year round	1 light vehicle specialising in combating birdstrikes **	1	2 pistols + firecracker rockets	2 12-bore guns or 16-bore guns + lead cartridges	Distress calls Remote controls Noisemakers
D	1 LC 1 OP1 seasonal + 1 OP2 the rest of the year	1 light vehicle specialising in combating birdstrikes **	1	2 pistols + firecracker rockets	2 12-bore guns or 16-bore guns + lead cartridges	Distress calls Remote controls Noisemakers
C	1 LC 1 OP2	1 vehicle equipped for combating birdstrikes usable on request	1	1 pistol + firecracker rockets	1 12-bore gun or 16-bore gun + lead cartridges	Distress calls Remote controls Noisemakers
B	1 LC 1 OP2	1 vehicle		1 pistol + firecracker rockets		
A	1 LC	Only information on bird activities is provided				

LC: Local Coordinator
OP1: Operative permanently present for combating the birdstrike hazard
OP2: Operative available on request for combating the birdstrike hazard

* : The choice of resources and their deployment is studied by the STNA for each airfield.
**: The type of vehicle is decided jointly with the LC, the STNA and the field operator.

ANNEXE B

Prévention du Péril Aviaire

Liste des Aérodromes en conformité avec l'arrêté du 24 juillet 89

AERODROMES	GROUPE	AERODROMES	GROUPE
AGEN	B	LE PUY	B
AJACCIO	C	LE TOUQUET	C
ALBI	B	LILLE	C
ANGERS	B	LIMOGES	B
ANNECY	B	LOGNES	B
AURILLAC	B	LYON BRON	C
AUXERRE	B	LYON SATOLAS	E
AVIGNON	B	MACON	B
BALE	C	MARSEILLE	E
BASTIA	C	MEAUX	B
BEAUVAIS	C	MELUN	B
BELLE EN ILE EN MER	B	MERVILLE	B
BERGERAC	B	METZ NANCY LORRAINE	C
BEZIERS	B	MONTLUCON	B
BIARRITZ	C	MONTPELLIER	D
BORDEAUX MERIGNAC	E	MORLAIX	C
BOURGES	B	NANCY	B
BREST	C	NANTES	D
BRIVE	B	NEVERS	B
CAEN	C	NICE COTE D AZUR	E
CALAIS	C	NIORT	B
CALVI	C	OUESSANT	B
CANNES	C	PARIS Le Bourget	D
CARCASSONNE	B	PARIS Orly	D
CHAMBERY	C	PAU	C
CHARLEVILLE	B	PERPIGNAN	C
CHAVENAY	B	POITIERS	B
CHATEAUROUX	C	PONTOISE	B
CHERBOURG	C	QUIMPER	C
CHOLET	B	RENNES	C
CLERMONT FERRAND	B	ROCHEFORT	C
COLMAR	B	RODEZ	B
DEAUVILLE	C	ROISSY CDG	D
DINARD	C	ROUEN	C
DOLE	C	ROYAN	B
EPINAL	B	SAINT BRIEUC	C
ETAMPES	B	SAINT CYR	B
FIGARI	B	SAINT ETIENNE	B
GRENOBLE Le Versoud	B	SAINT NAZAIRE	C
GRENOBLE St Geoirs	C	SAINT YAN	C
ILE D'YEU	B	TARBES	D
LA BAULE	B	TOULOUSE	D
LANNION	C	TOUSSUS	B
LA ROCHELLE	C	TROYES	B
LA ROCHE SUR YON	B	VALENCE	B
LAVAL	B	VANNES	B
LE HAVRE	C	VICHY	B
LE MANS	B		

APPENDIX C

Bird strike statistics in France

I. DATA SOURCES

The implementaion of bird control services on aerodromes has allowed many more collisions with birds data forms to be collected mainly drawn-up from bird remains found on runways. The number of birds strikes thus recorded in France has grown from 500 in 1985-1987 to 700 in 1991. Henceforth, 45% of the data comes from aerodromes, 35% from pilots and 35% from aircraft maintenance workshops.

II. EVOLUTION OF THE RISK OF STRIKES WITH BIRDS IN FRANCE

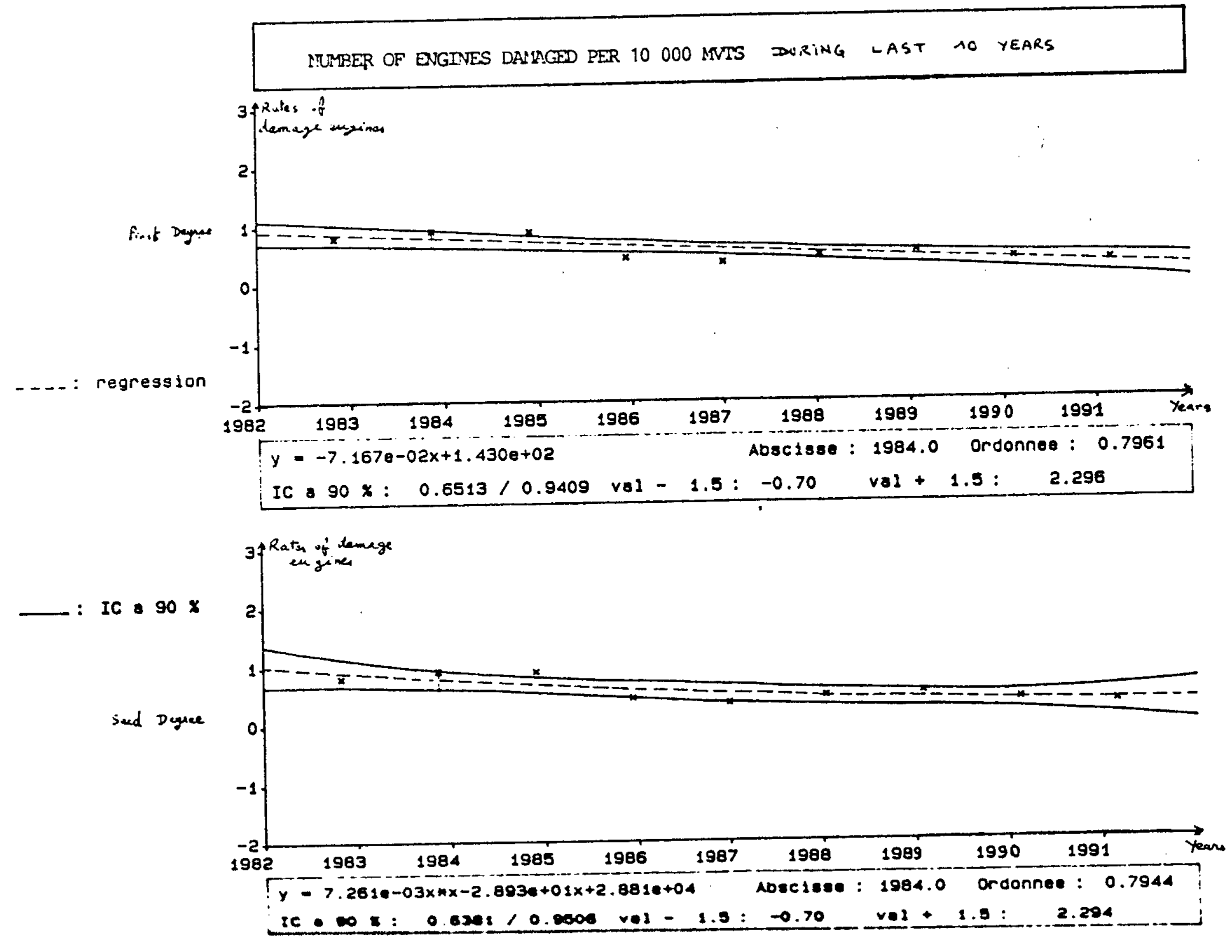
The increase in the total number of birdstrikes does not indicate a worsening of the risks, but rather an improvment in data collection especially that concerning semi-incidents i.e. previously non registred incidents entailing no damage. The proportion of these birds strikes with no resulting damage has thus increased each year. It has grown from 70% in the 1980s to 85% in 1990-1991.

A good indication of the evolutive tendency of the birds hazards in France is the number of engines damaged per 10 000 commercial aircraft movements. (These serious incidents have been well registered over a period of several years). This rate has decreased from 1 per 10 000mvts in 1983, to 0.6 per 10 000mvts in 1991 (see graph A), whilst the aircraft in operation are increasingly vulnerable to the ingestion of birds in their engines (a Caravelle ingested about ten times less birds than an Airbus, a B767 or a B737 equipped with CFM56 engines).

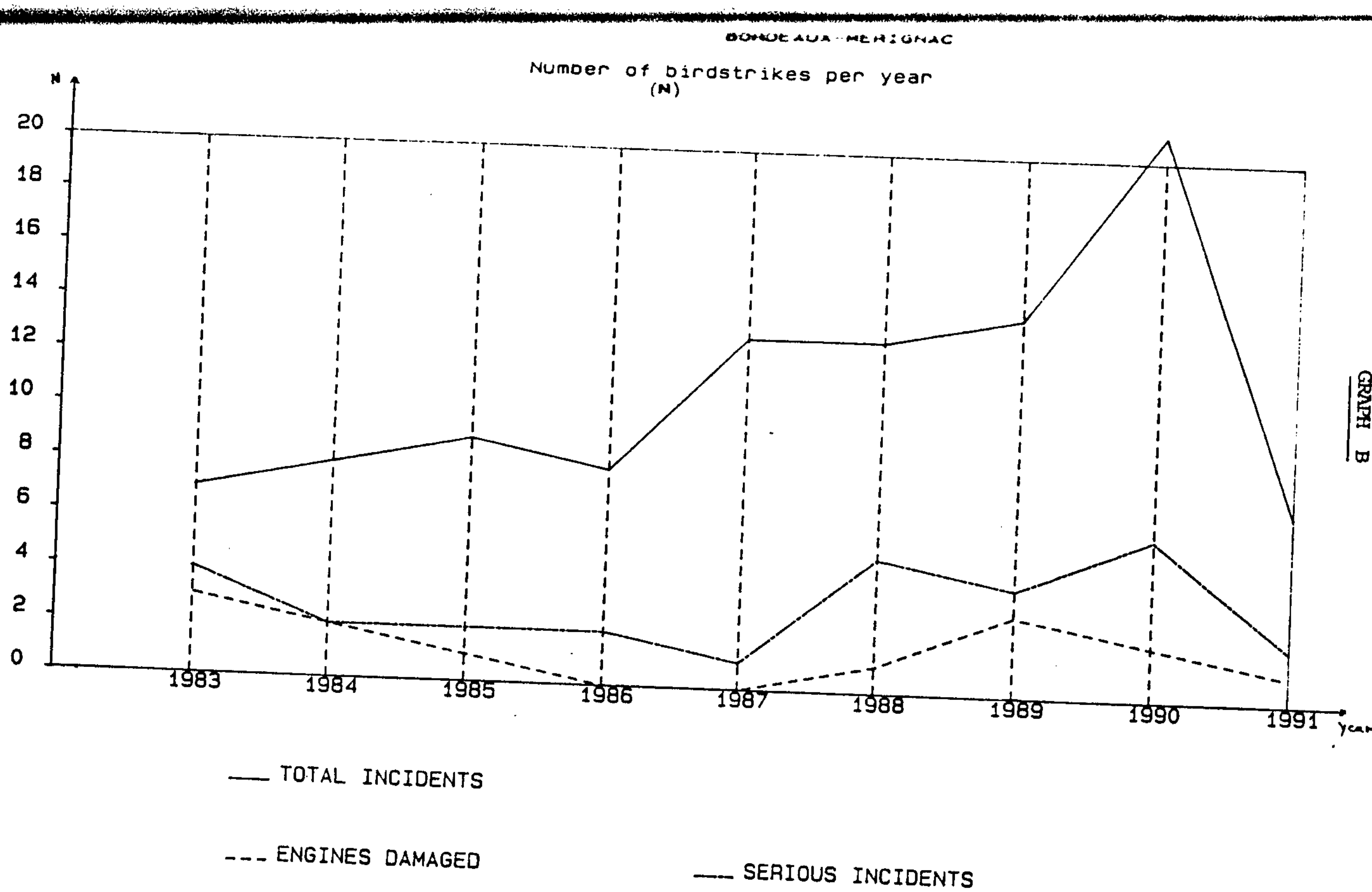
I. EVOLUTION AT AERODROME LEVEL

Since 1989, the measures taken against birds have proved successful for several major French airports (Bordeaux, Paris Charles de gaulle, graphs B-C) where a decrease of 50% in the number of engines damaged by birds has been recorded. The situation has remained stable for airports where intensive measures have been taken against birds over a period of several years (Marseille Provence, graph D).

GRAPH A



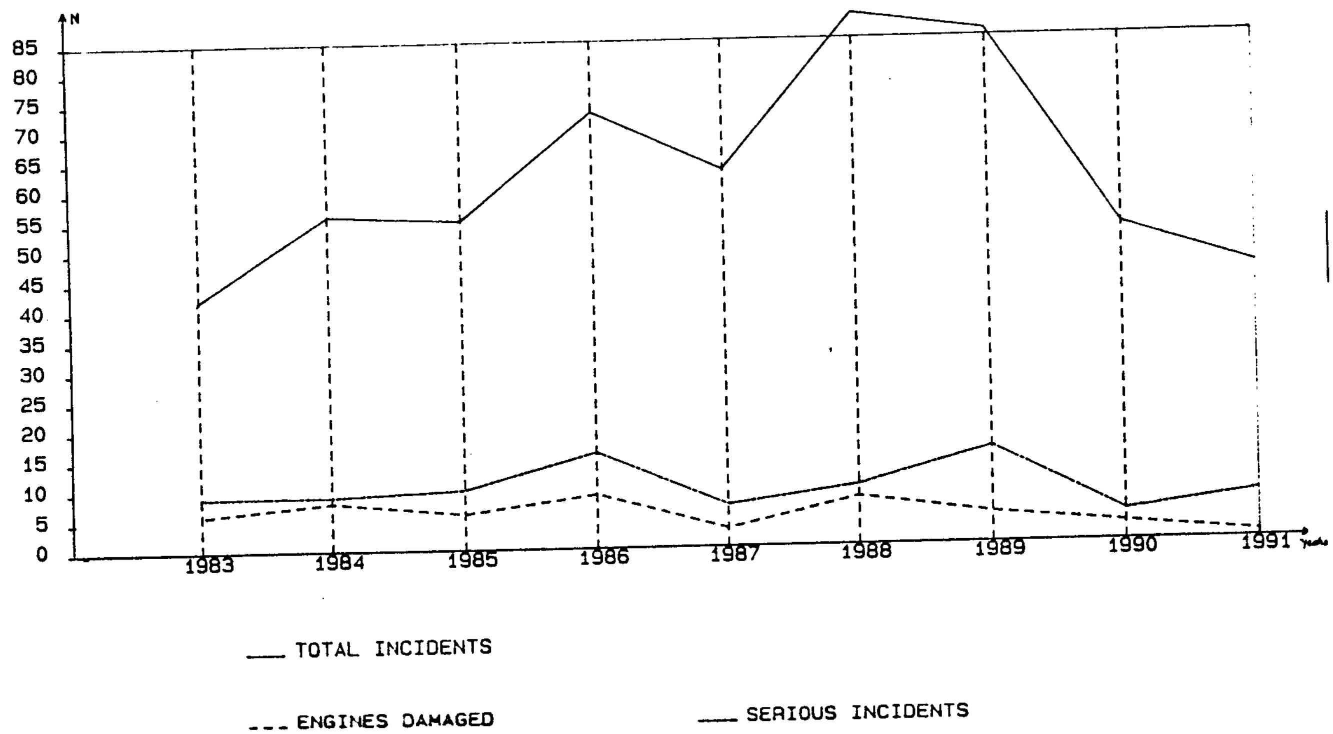
GRAPH B



GRAPH C

PARIS-CHARLES-DE-GAULLE

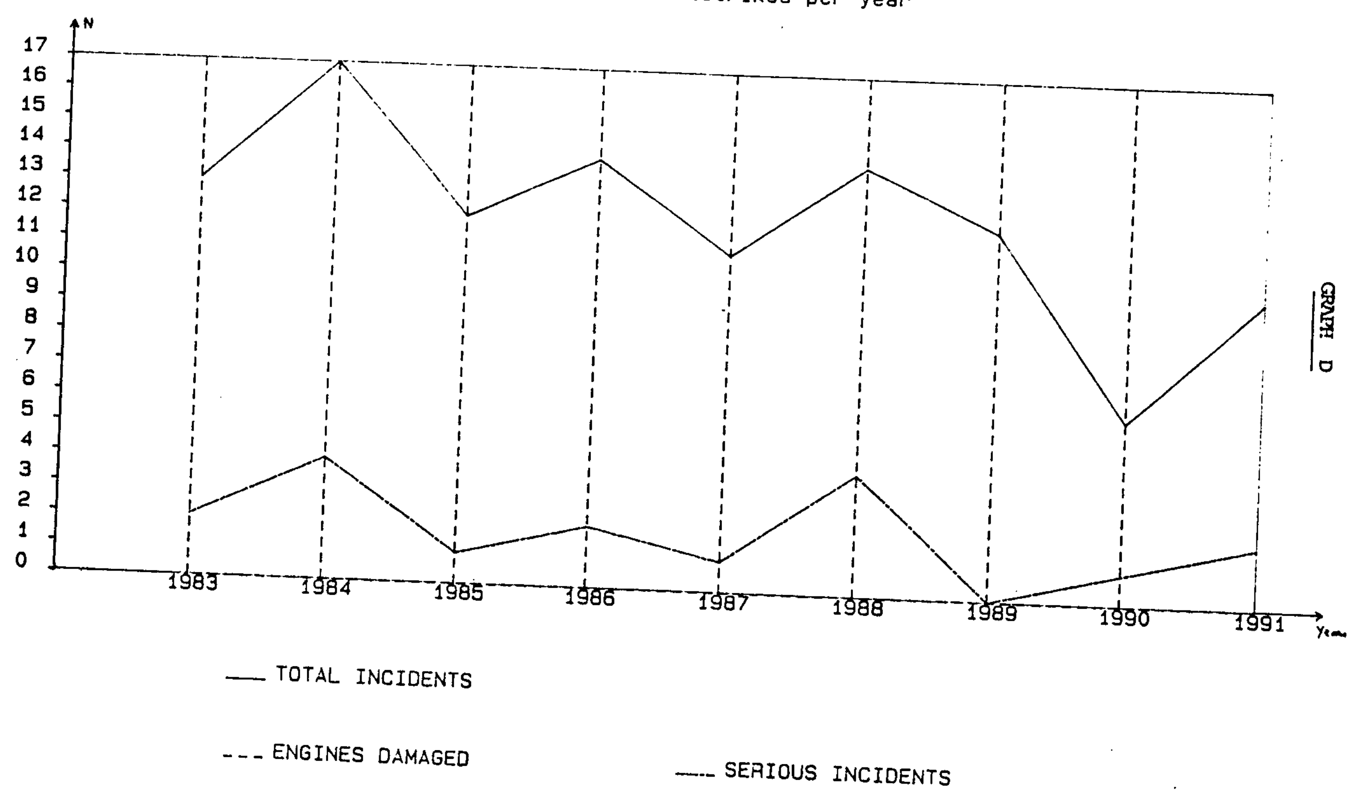
Number of birdstrikes per year



GRAPH D

MARSEILLE-PROVENCE

Number of birdstrikes per year

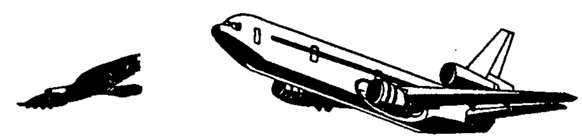


21st MEETING OF THE BSCE
(JERUSALEM 23-28 March 1992)

WP 21

PICA

Programme
d'Information
sur les Collisions
Aviaires



DGAC

STNA/2N

A. EUDOT

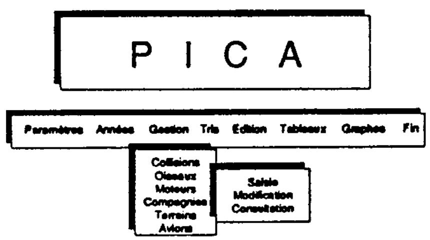
PICA

STNA/2N

PICA allows to manage birdstrikes database at a national level

Quick and easy to use,

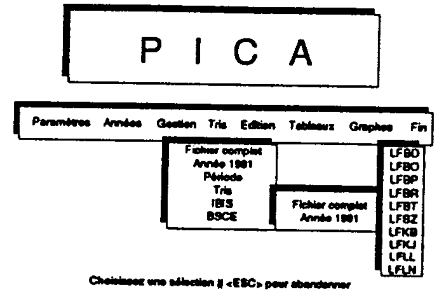
PICA prints forms, tables and graphs.



Création de nouvelles fiches

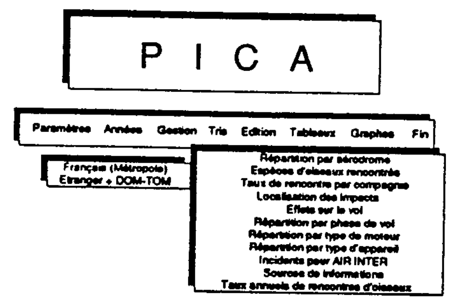
The choice of operations is done by scrolling menus.
Help messages on the bottom of the screen guides the user.

For instance, for printing birdstrikes file according to TOULOUSE-BLAGNAC, there are different menus will appear on screen.



Choisissez une sélection || <ESC> pour abandonner

And for printing table concerning the birdstrikes number for domestic airfields in 1991, consecutive menus will appear:



Collisions pour les aérodromes français

21st MEETING OF THE BSCE
(JERUSALEM 23-28 March 1992)

PICA: a bird strike information program

(Presented by A. EUDOT)

SUMMARY

The PICA version presented is a compiled version which can thus be used on any IBM-PC compatible micro-computer without using any software program other than the PICA. Data base management, consultation, exploitation (list editing, sortings, table and graph editing...), are now easier through a more sophisticated ergonomics than that of the former version (scrolling menus, help messages, execution speed...).

The version presented here is the french version of the PICA program, although an appropriat translation of the texts would enable it to be adapted to the requirements of any user.

When you want to use PICA, at first, you have to choose the year on which you want to work. (For instance: 1990). The main menu appears, which proposes you different choices of actions. Those different choices are:

PARAMETERS: especially for choosing output devices. You can print data on printer directly or record data in a special file.

YEAR : if you want to change the working year.

MANAGEMENT: proposes the management of different databases.

SORTS : for selecting different criteria of sorts and create sorts files.

OUTPUT : proposes different data output in the form of lists (or tables for BSCE output).

TABLES : printing out differents tables.

GRAPHS : printing out graphs for a specific airfield or for all data.

HELICOPTER: it's a special procedure for taking out data on birdstrikes with helicopters. This procedure was developped in order to propose a certification standard for helicopters.

MANAGEMENT OF DIFFERENT DATABASES

You can manage:

BIRDSTRIKES DATABASE

BIRDS DATABASE

ENGINES DATABASE

AIRLINES OPERATORS DATABASE

AIRFIELDS DATABASE

AIRCRAFT DATABASE

For each one, you can enter, modify or consult data.

DATA ENTRY AND MODIFICATION

It's about the same procedure for entering or modifying data: for instance, if you want to modify a birdsrike data, first you have to choose the criterion that will allow to find the right record to modify. (e.g. modify an Air France aircraft birdstrike, you select with F2 key "operator" and you're inputing "1991AF"). You are now on the first record concerning Air France operator in 1991. With Page Down key, you're finding the record you want to modify. When you have found it, press <ENTER> and you can modify the field names that you want, (e.g. modify field name concerning "bird species" and if you don't know the code of this bird, press F5 key and choose the right bird, e.g. PLUV.DOR: golden plover).
When the modification is done, press <ESC> and <ESC> again if you have no more record to modify.

SORT

At first, you're creating the sorting:
  for instance:
    operator
    is equal to
    AF (Air France)
    AND
    aircraft
    is equal to
    EA30 (Airbus A300)
    end of combinations.

Then you give a name to the sort file (e.g. EA30_AF)

OUTPUT

You can print:
- all the birdstrikes file
- a file for working year

- output for a given period
- sorting output for all the file or for working year. Then you choose the sort file in the list proposed (appendix 1).
- IBIS output:this is the IBIS code transcription of the birdstrike form for the working year
- BSCE output: at first, the computer is calculating the number of records which concerns BSCE data (according to the weight of aircraft, french operators only and so on). Then, the different tables supplied yearly to the BSCE Statistics working group, can be printed directly (e.g. parts struck, appendix 2).

TABLES OUTPUT

Different tables can be printed. (e.g. bird species distribution for working year. At first, computer is counting the number of records for which the bird species is known and then counts the number of cases (total and serious) and the rate by species. Appendix 3).

GRAPHS OUTPUT

You can choose to plot general graphs or graphs concerning a given airfield. If you choose graphs concerning an airfield, you have to choose this airfield in the list. (e.g. Bordeaux-Mérignac). Different graphs can be printed (e.g. month distribution. Computer is calculating the number of strikes and the number of serious strikes for each month of the working year, appendix 4). The graph is presented on the screen. Then the computer suggests an output on the plotter.

HELICOPTERS

It's a special procedure developped for giving statistical data on birdstrikes with different types of helicopters, in order to propose standard for helicopters of certification. (e.g. distribution of birdstrikes according to bird weights, appendix 5.)

If anybody is interested by additional information, I'm ready to show you demonstrations on my portable micro-computer.

For more information on PICA, using and acquisition, you can contact M. A. EUDOT:
STNA/2N 246, Rue LECOURBE
75732 PARIS CEDEX 15 FRANCE
TEL: 33 (1) 40 43 47 33
FAX: 33 (1) 40 43 47 92

SELECTION : EA30_AF POUR L'ANNEE 1990

DATE HEURE	LIEU PISTE	AVION MOTEUR	CIE JOUR	HAUT-ft VIT-kt	VOL MTO	OISEAU TAILLE	VUS TOUCHES	PARTIES TOUCHEES ET DEGATS OBSERVES	IMMAT COUT(F)	INFORMATION PIL. AVERTI	EFFET	OBSERVATIONS
19/02/90 19.07	LFPG 28	EA30 CF6.50C2R	AF N	70 150	APP	MOYEN	1	FUSE L	FBVGL ?	PIL NON	AUCUN SELAGE.@	ENFONCEMENT FU
21/03/90 16.03	LFPG 27	EA30 CF6.50C2R	AF J	0 175	DEC	MOYEN	2 à 10 2 à 10	MOT1 G	TUTAO 250000	PIL NON	ATTPRUD .CARBURANT.RETARD:7H30	4 AUBES HS.VID
05/05/90 04.20	LFKJ 21	EA30 CF6.50C2R	AF J	0 120	DEC	MOUET.RI MOYEN	2 à 10 2 à 10	MOT1 G	FBVGB ?	TER NON	DEC.INT	GTR CHANGE.@
10/05/90 16.30	LFPO 26	EA30 CF6.50C2R	AF J	1300 160	DES	PETIT	2 à 10 1	RADO N	FBVGA ?	PIL NON	AUCUN	@
27/06/90 20.25	LFMN	EA30 CF6.50C2R	AF	? ?	ATT	GOEL.ARG GRAND	1	MOT2 N	FBVGB ?	DM NON	AUCUN	@
13/07/90	LFPG 10	EA30 CF6.50C2R	AF J	200 140	DES	HIR/MART PETIT	1	PARE N	FBVGN ?	PIL NON	AUCUN	@
17/07/90 13.50	LFPG 10	EA30 CF6.50C2R	AF J	0 ?	DEC	MOUET.RI MOYEN	11 à 100 1		FBVGJ ?	TER OUI	AUCUN	@
27/07/90 07.58	LFPO 07	EA30 CF6.50C2R	AF J	300 130	DES	PETIT	2 à 10 2 à 10	RADO N PARE N MOT2 N	FGBEC ?	PIL NON	AUCUN	@
28/07/90	LFPG	EA30 CF6.50C2R	AF J	? ?	ATT	PIGEON.C MOYEN	1	MOT1 N	FBVGR ?	DM NON	AUCUN	@
13/08/90 15.58	LTBA 06	EA30 CF6.50C2R	AF J	0 120	DEC	GOEL.ARG GRAND	11 à 100 2 à 10	MOT2 N AILE N TRAI N	FBVGO ?	DM+PIL NON	AUCUN	@
30/08/90	LFPG	EA30 CF6.50C2R	AF	? ?	ATT	PEDRI.GR MOYEN	1		FBVGB ?	DM NON	AUCUN	@

Appendix 2

PARTIES TOUCHEES POUR L'ANNEE 1990

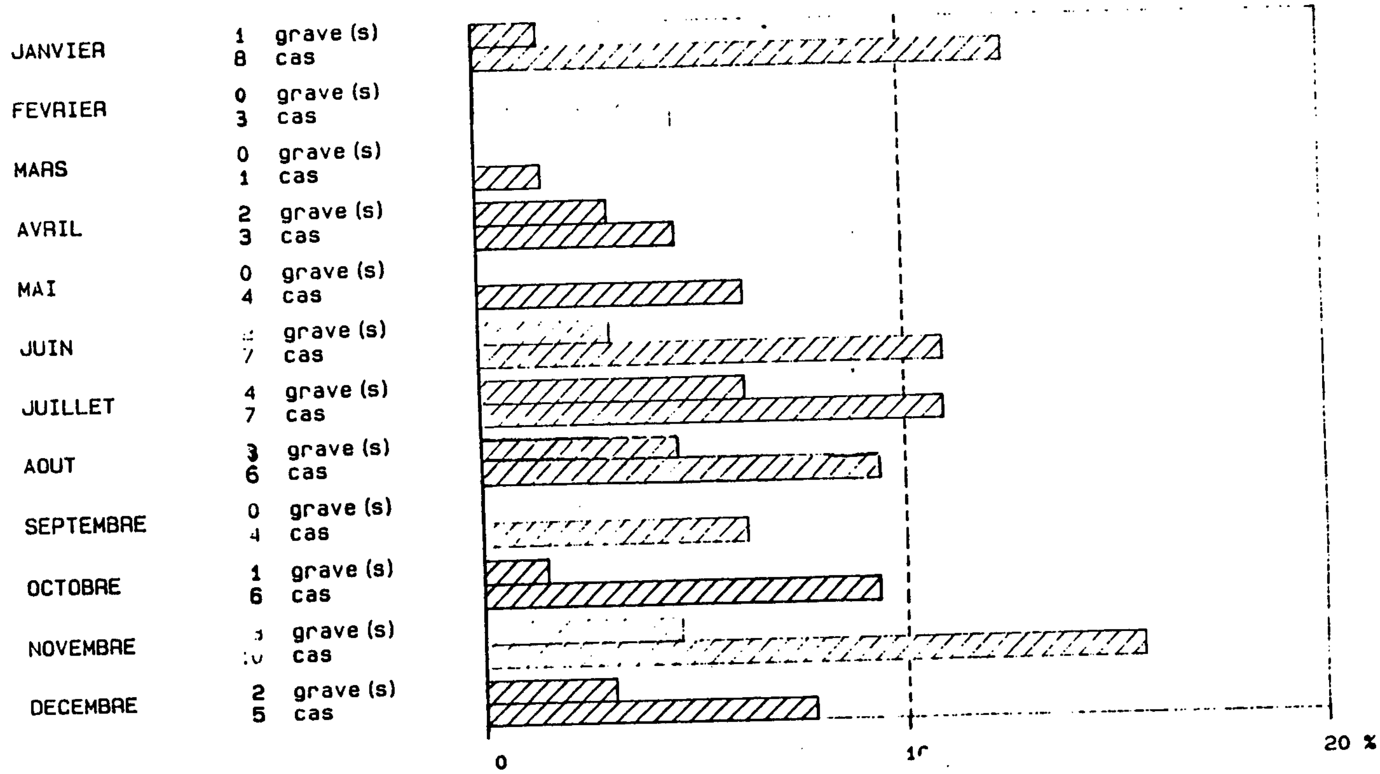
PARTIE	FUSE-LAGE	NEZ	RADO-ME	PARE-BRISE	MOTEUR	AILE ROTOR	TRAIN	EMPEN-NAGE	INCON-NU	TOTAL	% BASE SUR 419 CAS
INCONNU	5	22	23	21	87	17	6	1	7	189	45.1
CATEGORIE A	1	5	8	12	21	5	5	1	2	60	14.3
CATEGORIE B	16	20	13	17	103	31	25	3	37	265	63.2
CATEGORIE C										0	0.0
CATEGORIE D										0	0.0
TOTAL	22	47	44	50	211	53	36	5	46	514	
% BASE SUR 419 CAS	5.3	11.2	10.5	11.9	50.4	12.6	8.6	1.2	11.0		

Appendix 3

ESPECE D'OISEAUX RENCONTREES EN 1991

ESPECE D'OISEAUX		POIDS (g)	NOMBRE DE CAS		% BASE SUR 462 CAS
NOM COMMUN	NOM LATIN		TOTAL	AV.DOMMAGE	
ALOUETTE DES CHAMPS	ALAUDA ARVENSIS	38	1		0.2
BECASSE DES BOIS	SCOLOPAX RUSTICOLA	300	2	1	0.4
BRUANT PROYER	EMBERIZA CALANDRA	48	2	1	0.4
BUSARD DES ROSEAUX	CIRCUS AERUGINOSUS	630	2		0.4
BUSARD SAINT-MARTIN	CIRCUS CYANEUS	430	5	1	1.1
BUSE OU MILAN		900	4	2	0.9
BUSE VARIABLE	BUTEO BUTEO	800	21	3	4.5
CHEVALIER COMBATTANT	PHILOMACHUS PUGNAX	140	1		0.2
CHOUCAS DES TOURS	CORVUS MONEDULA	234	1	1	0.2
CHOUETTE CHEVECHE	ATHENA NOCTUA	164	2		0.4
CHOUETTE EFFRAIE	TYTO ALBA	315	7		1.5
CORBEAU FREUX	CORVUS FRUGILEGUS	430	13	1	2.8
CORNEILLE NOIRE	CORVUS CORONE	530	5		1.1
COUCOU GRIS	CUCULUS CANORUS	106	1		0.2
EPERVIER D'EUROPE	ACCIPITER NISUS	190	1		0.2
ETOURNEAU SANSONNET	STURNUS VULGARIS	80	4		0.9
FAUCON CRECERELLE	FALCO TINNUNCULUS	205	66	2	14.3
GOELAND ARGENTE	LARUS ARGENTATUS	1100	28	4	6.1
GOELAND BRUN	LARUS FUSCUS	820	2	1	0.4
GRAND CORMORAN	PHALACROCORAX CARBO	2430	1		0.2
GRIVE DRAINE	TURDUS VISCIVORUS	125	1		0.2
GRIVE MUSICIENNE	TURDUS PHILOMELOS	74	3		0.6
GUEPIER D'EUROPE	MEROPS APIASTER	51	1		0.2
HERON BIHOREAU	NYCTICORAX NYCTICORAX	670	1		0.2
HERON CENDRE	ARDEA CINEREA	1500	3	1	0.6
HIBOU BRACHYOTE	ASIO FLAMMEUS	355	4		0.9
HIBOU MOYEN-DUC	ASIO OTUS	275	5		1.1
HIRONDELLE DES CHEMINEES	HIRUNDO RUSTICA	18	6		1.3
HIRONDELLE DES FENETRES	DELICHON URBICA	17	1		0.2
HIRONDELLES OU MARTINETS	HIRUNDINIDAE OU APODIDAE	30	22		4.8
INCONNUS			165	14	
LARIDE	LARIDAE		1		0.2
MARTINET NOIR	APUS APUS	40	29	1	6.3
MILAN NOIR	MILVUS MIGRANS	780	22	1	4.8
MILAN ROYAL	MILVUS MILVUS	1020	2	2	0.4
MOINEAU DOMESTIQUE	PASSER DOMESTICUS	28	1		0.2
MOUETTE RIEUSE	LARUS RIDIBUNDUS	275	68	5	14.7
MOUETTE TRIDACTYLE	RISSA TRIDACTYLA	390	1		0.2
MOUETTES OU GOELANDS	LARIDAE		2		0.4
OEDICNEME CRIARD	BURHINUS OEDICNEMUS	450	2	1	0.4
PASSEREAUX	PASSERIFORMES	20	2		0.4
PERDRIX GRISE	PERDIX PERDIX	400	8	2	1.7
PERDRIX ROUGE	ALECTORIS RUFA	450	1		0.2
PIGEON DOMESTIQUE	COLUMBA LIVIA	393	5		1.1
PIGEON RAMIER	COLUMBA PALUMBUS	465	19	6	4.1
PIGEON SP.	COLUMBIDAE	400	3	2	0.6
PIPIT FARLOUSE	ANTHUS PRATENSIS	18	2		0.4
RAPACES DIURNES	ACCIPITRIDAE		9	1	1.9
STRIGIDE	STRIGIDAE	270	2		0.4
TOURTERELLE DES BOIS	STREPTOPELIA TURTUR	145	1		0.2
TRAQUET PATRE	SAXICOLA TORQUATA	14	1		0.2
VANNEAU HUPPE	VANELLUS VANELLUS	215	65	6	14.1

REPARTITION PAR MOIS POUR L'ANNEE 1989 A PARIS-ORLY



Collisions oiseaux-hélicoptères

Bird Weight (in pounds)	Number of strikes		Percentage	
	Total	Dammaged	Total	Dammaged
W < 1/4	68	22	33.8 %	10.9 %
W < 1/2	87	24	43.3 %	11.9 %
W < 1	138	36	68.7 %	17.9 %
W < 2	169	50	84.1 %	24.9 %
W < 4	190	57	94.5 %	28.4 %
W < 8	198	62	98.5 %	30.8 %
TOTAL	201	64	100.0 %	31.8 %

BSCE 21/WP 22
Jerusalem 1992

THE DIVERSITY OF FEATHERPRINTS IN THE CHARADRIIFORMES AND IN THE ANSERIFORMES

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Zoological Institute, K.U.Leuven, Naamsestraat 59,
B-3000 Leuven, Belgium

SUMMARY

Scanning electron microscopy pictures (called featherprints) of the feather surface, of 65 charadriiform species belonging to 31 genera and 13 families, were studied to shed some light on their diversity and on their identification value. We started our descriptions with the different aspects of the obverse rachis surface (site IX). Marked differences in the featherprint formulae of nearly all species could be observed except in the Three-banded Plover *Charadrius tricollaris* (F. Charadriidae) and the Redshank *Tringa totanus* (F. Scolopacidae). An identification key is presented. Sixteen anseriform species were examined similarly. Clear-cut differences were noticed between ducks, geese and swans.

Keywords: featherprints, SEM, Charadriiformes, Anseriformes

INTRODUCTION

Birds have been recognized as a potential hazard to safe operation of aircraft since the inception of the first aeroplane service (ICAO 1978). One of the first steps in reducing this risk is establishing which species are most likely to cause an accident. Only when a detailed insight regarding the species most frequently involved in bird strikes has been obtained, the most adequate preventive measures may be taken.

Apart from preliminary biochemical studies of blood and flesh remains (De Bont *et al.* 1986), attention has been focused on the identification of feathers and feather fragments (Brom 1980, 1986, 1991). The reason for this is that nearly always feather remains are present in the bird remains. Up till recently none of the morphological methods used in feather research was completely satisfactory. So I developed a new method. Studying the drawings on the rachis, rami and rachidial barbules of the feathers by means of a scanning electron microscope very promising results were obtained (Perremans 1990). The method has been successfully used for the identification of the birds involved in a series of bird strikes.

In this paper the submicroscopic characteristics, at a scanning electron microscope level, of 65 Charadriiformes and of 16 Anseriformes are described. Marked diferences in featherprint formulae were noticed. A key is presented for the charadriiform species.

MATERIAL AND METHODS

I studied 65 charadriiform species belonging to 31 genera and 13 families and 16 anseriform species belonging to 12 genera and 1 family.
The following Charadriiformes were examined:
.Jacanidae: African Jacana *Actophilornis africana* (Gmelin, 1789); Wattled Jacana *Jacana jacana* (Linnaeus, 1766);
.Rostratulidae: Painted Snipe *Rostratula benghalensis* (Linnaeus, 1758);
.Haematopodidae: African Black Oystercatcher *Haematopus moquini* Bonaparte, 1856; Oystercatcher *Haematopus ostralegus* Linnaeus, 1758;
.Recurvirostridae: Black-winged Stilt *Himantopus himantopus* (Linnaeus, 1758);
.Burhinidae: Spotted Thick-Knee *Burhinus capensis* (Lichtenstein, 1823); Senegal Thick-Knee *Burhinus senegalensis* (Swainson, 1837); Water Thick-Knee *Burhinus vermiculatus* (Cabanis, 1868); Stone Curlew *Burhinus oedicnemus* (Linnaeus, 1758);
.Glareolidae: Egyptian Plover *Pluvianus aegypticus* (Linnaeus, 1758); Collared Pratincole *Glareola pratincola* (Linnaeus, 1766); Black-winged Pratincole *Glareola nordmanni* Fischer, 1842; Temminck's Courser *Cursorius temminckii* Swainson, 1822; Grey Pratincole *Glareola cinerea* Fraser, 1843; Rock Pratincole *Glareola nuchalis* Gray, 1849;
.Charadriidae: Lapwing *Vanellus vanellus* (Linnaeus, 1758); Three-banded Plover *Charadrius tricollaris* Vieillot, 1818; White-fronted Plover *Charadrius marginatus* Vieillot, 1818; Caspian Plover *Charadrius asiaticus* Pallas, 1773; Grey Plover *Pluvialis squatarola* (Linnaeus, 1758); Lesser Black-winged Lapwing *Vanellus lugubris* (Lesson, 1826); Crowned Lapwing *Vanellus coronatus* (Boddaert, 1783); Spur-winged Lapwing *Vanellus spinosus* (Linnaeus, 1758); African Wattled Lapwing *Vanellus senegallus* (Linnaeus, 1766); Brown-chested Lapwing *Vanellus superciliosus* (Reichenow, 1886); Long-toed Lapwing *Vanellus crassirostris*

(Hartlaub, 1855); Ringed Plover *Charadrius hiaticula* Linnaeus, 1758; Little Ringed Plover *Charadrius dubius* Scopoli, 1786; Kittlitz's Plover *Charadrius pecuarius* Temminck, 1823; Forbes' Plover *Charadrius forbesi* (Shelley, 1883); Golden Plover *Pluvialis apricaria* (Linnaeus, 1758);
.Scolopacidae: Black-tailed Godwit *Limosa limosa* (Linnaeus, 1758); Woodcock *Scolopax rusticola* Linnaeus, 1758; Snipe *Gallinago gallinago* (Linnaeus, 1758); Marsh Sandpiper *Tringa stagnatilis* (Bechstein, 1803); Greenshank *Tringa nebularia* (Gunnerus, 1767); Redshank *Tringa totanus* (Linnaeus, 1758); Whimbrel *Numenius phaeopus* (Linnaeus, 1758); Great Snipe *Gallinago media* (Latham, 1787); Turnstone *Arenaria interpres* (Linnaeus, 1758); Ruff *Philomachus pugnax* (Linnaeus, 1758); Curlew Sandpiper *Calidris ferruginea* (Pontoppidan, 1763); Little Stint *Calidris minuta* (Leisler, 1812); Sanderling *Calidris alba* (Pallas, 1764); Common Sandpiper *Actitis hypoleucos* Linnaeus, 1758; Green Sandpiper *Tringa ochropus* Linnaeus, 1758; Wood Sandpiper *Tringa glareola* Linnaeus, 1758; Dunlin *Calidris alpina* (Linnaeus, 1758);
.Stercorariidae: Great Skua *Stercorarius skua* Brünnich, 1764;
.Laridae: Black-headed Gull *Larus ridibundus* Linnaeus, 1766; Grey-headed Gull *Larus cirrocephalus* Vieillot, 1818; Kelp Gull *Larus dominicanus* Lichtenstein, 1823; Common Gull *Larus canus* Linnaeus, 1758; Kittiwake *Rissa tridactyla* (Linnaeus, 1758); Herring Gull *Larus argentatus* Pontoppidan, 1763;
.Sternidae: Sandwich Tern *Sterna sandvicensis* Latham, 1787; Common Tern *Sterna hirundo* Linnaeus, 1758; White-winged Black Tern *Chlidonias leucopterus* (Temminck, 1815); Swift Tern *Sterna bergii* Lichtenstein, 1823;
.Rynchopidae: African Skimmer *Rynchops flavirostris* Vieillot, 1816;
.Alcidae: Razorbill *Alca torda* Linnaeus, 1758; Puffin *Fratercula arctica* (Linnaeus, 1758); Guillemot *Uria aalge* (Pontoppidan, 1763); Little Auk *Alle alle* (Linnaeus, 1758).
The following Anseriformes were examined:
.Anatidae: Shelduck *Tadorna tadorna* (Linnaeus, 1758), Mandarin *Aix galericulata* (Linnaeus, 1758), Wigeon *Anas penelope* Linnaeus, 1758, Gadwall *A.strepera* Linnaeus, 1758, Mallard *A.platyrhynchos* Linnaeus, 1758, Pintail *A.acuta* Linnaeus, 1758, Shoveler *A.clypeata* Linnaeus, 1758, Pochard *Aythya ferina* (Linnaeus, 1758), Common Scoter *Melanitta nigra* (Linnaeus, 1758), Goldeneye *Bucephala clangula* (Linnaeus, 1758), Smew *Mergus albellus* (Linnaeus, 1758), White-backed Duck *Thalassornis leuconotus* Eyton, 1838, Maccoa Duck *Oxyura maccoa* (Eyton, 1838), Southern Pochard *Netta erythrophthalma* (Wied, 1832), Mute Swan *Cygnus olor* (Gmelin, 1789), Greylag Goose *Anser anser* (Linnaeus, 1758).

An intraspecific study established that there are only very slight differences in the featherprints of feathers originating from different parts of the body (Perremans 1990, Perremans *et al.* in press). Therefore only the ninth primary was used in this SEM study.

Nine sites of a feather (Perremans 1990: Fig. 1 and 2) were described: the reverso-lateral surface of the rachis below the rami (site I), the same surface between the rami (site 2), the proximal (site 3) and the distal (site IV) surface of a ramus below the barbules, the reverse surface of the base of the rachidial barbules (site V), the obverso-lateral surface of the rachis between the rami (site 6), the proximal (site VII) and the distal (site VIII) surface of a ramus above the barbules and the obverse surface of the rachis (site IX). For a description of the encountered features see Perremans (1990) and Perremans *et al.* (in press).

RESULTS

First the results of the Charadriiformes will be treated. I have found four different features (deep pits (DP), very small pits (VSP), relatively smooth (RS) and honey comb structure (HC)) on site IX. Cell boundaries are of type 1 (fine, deep laying lines) or type 6 (no cell boundaries visible). The cell surface is flat in all the examined species.

Two features are limited to one species: a relatively smooth (RS) obverse rachis surface is found in the Spotted Thick-Knee *Burhinus capensis* and a honey comb (HC) structure is found in the African Skimmer *Rynchops flavirostris*.

There are very small pits (VSP) at site IX in 19 species. Six of these species show cell boundaries of type 6 (Table 1). All species are recognizable by differences at other sites. Eleven of these species show cell boundaries of type 1 (Table 2). The species are recognizable by differences at other sites (Table 2). The two species (African Jacana *Actophilornis africana* and Swift Tern *Sterna bergii*) whose type of cell boundary at site IX is unknown differ as well from all the species of Table 1 as from all the species of Table 2.

The remaining species (n = 44) possess deep pits (DP) at site IX. Ten of these species show cell boundaries of type 6 (Table 3). All formulae of Table 3 are different. The remaining 34 species show cell boundaries of type 1 (Table 4). All the featherprint formulae of Table 4 are different except those of the Three-banded Plover *Charadrius tricollaris*, the Long-toed Lapwing *Vanellus crassirostris* (both Charadriidae) and the Redshank *Tringa totanus* (Scolopacidae). The formula from the Long-toed Lapwing differs from the two others in the type of cell boundary.

In the Anseriformes all ducks (n=14) show a finely frayed surface with cell boundaries of type 5 (Fig. 1a, b) on site I, II, III, IV, VI and VII, the Greylag Goose and the Mute Swan show a completely different picture. In the two last species micropapillae are encountered on the reverse surface of the rachis. The goose and the swan differ from each other in the concentration of these micropapillae and in the type of cell boundary (Fig 1c, d).

DISCUSSION

I wanted to shed some light on the diversity of featherprints in the Charadriiformes and on their value as identification clues. The featherprint formulae of all examined species (n=65) with the exception of those of the Three-banded Plover *Charadrius tricollaris* (F. Charadriidae) and the Redshank *Tringa totanus* (F. Scolopacidae) showed marked differences.

This method together with the method of Brom (1980, 1986, 1991) offers the best possibilities when interested in bird identification starting from feathers or feather remains. The morphological studies of other authors (Gladstone 1918, Auber and Appleyard 1951, Auber 1955, 1957, Auber and Mason 1955, Rutschke

1960, 1966, Day 1966, Dyck 1971, 1973, 1990, Swales 1970, Lyster 1985, Horton 1990) are too fragmentary to be valid for an identification. When identifying bird remains from strikes it is impossible to use biochemical methods (such as electrophoresis: Ouellet and van Zyll de Jong 1990) because one never knows which changes your proteins have gone through. Also the analysis of keratin is unreliable because the relative amounts of amino acids vary among the calamus, barbs, and the cortex and the medulla of the rachis (Harrap and Woods 1964, 1967).

Until recently no large differences in feather structure between ducks, geese and swans (Anatidae, Anseriformes) could be detected (Chandler 1916, Brom 1980, Horton 1990). The number of terminal barbule nodes in downy barbules of Anatidae may vary considerably (1 to 10) according to Chandler (1916). This, however, is of no diagnostic value since large differences may be found, for this character, between feathers of the same bird (Brom 1980). Also, Brom (1980) did not find significant differences in the length of the downy barbules of various species of Anatidae. When measuring the part of the downy barbules that show heart-shaped nodes he found a difference, but not strictly deliminated, between ducks, geese and swans. The genus Tadorna showed lengths intermediate between ducks and geese. Horton (1990) could separate ducks from geese and swans using three measurements (base length BL, node width NW and internode length INL) on basal downy barbules of basal barbs taken from breast feathers of a number of anseriform species. A further separation was less successful.

In the preliminary SEM study, on the surface structures of the Anatidae, Anseriformes, clear-cut differences between ducks (n=14), a goose (n=1) and a swan (n=1) were discovered.

IDENTIFICATION KEY

The key will only permit identification of the 65 examined charadriiform species. It is strongly recommended to compare the obtained observations with a reference library (existing at the K.U.Leuven). The key can only be adopted for identification of feather remains when rachis parts are present.

1. Site IX relatively smooth..............Spotted Thick-Knee
   Site IX honey comb structure...........African Skimmer
   Site IX very small pits................2
   Site IX deep pits......................10
2. VSP with cell boundaries of type 6.....3
   VSP with cell boundaries of type 1.....5
3. Site I very roughly frayed............Oystercatcher
   Site I finely frayed..................Temminck's Courser
   Site I micropapillae of density b......Stone Curlew
   Site I micropapillae of density d......Collared Pratincole
   Site I micropapillae of density f......4
4. Site II finely frayed..................Egyptian Plover
   Site II very roughly frayed............Golden Plover

5. Site I very roughly frayed in the
presence of a few micropapillae........Kittiwake
Site I very roughly frayed.............Herring Gull
Site I roughly frayed..................Razorbill
Site I finely frayed...................9
Site I micropapillae of density b......7
Site I micropapillae of density d......6

6. Site III roughly frayed...............Black-tailed Godwit
Site III finely frayed.................Common Tern

7. Site VI roughly frayed................Senegal Thick-Knee
Site VI micropapillae of density d.....8

8. Site VII very roughly frayed..........Whimbrel
Site VII roughly frayed................Snipe

9. Site II finely frayed.................Great Skua
Site II roughly frayed.................Ruff
Site II very roughly frayed............Greenshank

10. DP with cell boundaries of type 6......11
DP with cell boundaries of type 1......17

11. Site I very roughly frayed............Common Gull
Site I finely frayed...................12
Site I micropapillae of density b......Great Snipe
Site I micropapillae of density c......15
Site I micropapillae of density d......16

12. Site II finely frayed.................Wattled Jacana
Site II roughly frayed.................13

13. Site IV very roughly frayed...........Dunlin
Site IV roughly frayed.................14

14. Site VI very roughly frayed...........Green Sandpiper
Site VI roughly frayed.................Common Sandpiper

15. Site II roughly frayed in the
presence of a few micropapillae........Black-winged Pratincole
Site II micropapillae of density c.....Woodcock

16. Site II very roughly frayed...........Brown-chested Lapwing
Site II roughly frayed.................Lapwing

17. Site I roughly frayed in the
presence of a few micropapillae........Caspian Plover
Site I very roughly frayed.............Little Auk
Site I roughly frayed..................18
Site I finely frayed...................21
Site I micropapillae of density b......33
Site I micropapillae of density c......34
Site I micropapillae of density d......35
Site I micropapillae of density f......36

18. Site III very roughly frayed..........Kelp Gull
Site III roughly frayed................19

19. Site VI roughly frayed................Puffin
Site VI very roughly frayed............20

20. Site VII very roughly frayed..........Little Stint
Site VII roughly frayed................Kittlitz's Plover

21. Site II very roughly frayed...........22
Site II roughly frayed.................26

22. Site III very roughly frayed..........Turnstone
Site III roughly frayed................23

23. Site IV very roughly frayed...........Wood Sandpiper
Site IV roughly frayed.................24

24. Site VI roughly frayed................Marsh Sandpiper
Site VI very roughly frayed............25

25. Site VIII very roughly frayed.........Grey Plover
Site VIII roughly frayed...............Sanderling

26. Site III very roughly frayed..........White-winged Black Tern
Site III roughly frayed................28
Site III finely frayed.................27

27. Site IV roughly frayed................Curlew Sandpiper
Site IV finely frayed..................Sandwich Tern

28. Site IV finely frayed.................Ringed Plover
Site IV very roughly frayed............29
Site IV roughly frayed.................30

29. Site VII very roughly frayed..........White-fronted Plover
Site VII roughly frayed................Guillemot

30. Site VI finely frayed.................Painted Snipe
Site VI roughly frayed.................31

31. Site VIII roughly frayed..............Forbes' Plover
Site VIII finely frayed................32

32. Site VI roughly frayed with cell
boundaries of type 6...................Long-toed Lapwing
Site VI roughly frayed with cell
boundaries of type 3...................Redshank and Three-banded Plover

33. Site II very roughly frayed in the
presence of a few micropapillae........Black-headed Gull
Site II roughly frayed in the
presence of a few micropapillae........Grey-headed Gull
Site II micropapillae of density b.....Water Thick-Knee

34. Site II very roughly frayed in the
presence of a few micropapillae........Black-winged Stilt
Site II very roughly frayed............Lesser Black-winged Lapwing
Site II roughly frayed.................African Wattled Lapwing
Site II micropapillae of density d.....African Black Oystercatcher

35. Site II very roughly frayed...........Crowned Lapwing
Site II finely frayed..................Rock Pratincole

36. Site II roughly frayed................37
Site II finely frayed..................Spur-winged Lapwing

37. Site VI roughly frayed................Little Ringed Plover
Site VI finely frayed..................Grey Pratincole

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LITERATURE CITED

Auber, L. 1955. Cortex and medulla of bird-feathers. Nature 176: 1218-1219.
Auber, L. 1957. The distribution of structural colours and unusual pigments in the class Aves. Ibis 99: 463-476.

Auber, L. and H.M. Appleyard 1951. Surface cells of feather barbs. Nature 168: 736-737.

Auber, L. and M.V. Mason 1955. Structurally coloured pattern marks on the inner webs of flight feathers. Ibis 97: 259-265.

Brom, T.G. 1980. Microscopic identification of feather remains after collisions between birds and aircraft: 1-89 (Mimeographed report, Amsterdam).

Brom, T.G. 1986. Microscopic identification of feathers and feather fragments of palearctic birds. Bijdr. Dierk. 56(2): 181-204.

Brom, T.G. 1991. The diagnostic and phylogenetic significance of feather structures. Thesis University of Amsterdam, the Netherlands.

Chandler, A.C. 1916. A study of the structure of feathers, with reference to their taxonomic significance. Univ. Calif. Publ. Zool. 13: 243-446.

Day, M.G. 1966. Identification of hair and feather remains in the guts and faeces of stoats and weasels. J. Zool. 148: 210-217.

De Bont A., J.F. Boomans, P. De Raeve, E. Hoet and B. Verachtert 1986. Strategies for the identification of bird remains from birdstrikes. Survey and advanced approach by biochemical analysis of tissues. 18th meeting BSCE, Copenhagen: 9pp.

Dyck, J. 1971. Structure and spectral reflectance of green and blue feathers of the Rose-faced Lovebird (*Agapornis roseicollis*). Biol. Skr. 18(2): 1-67.

Dyck, J. 1973. Feather structure: the surface of barbs and barbules. Zool. Jb. Anat. Bd. 90: 550-566.

Dyck, J. 1990. The ways in which feather colours are produced and their potential for identification of feather remains. 20th meeting BSCE, Helsinki, WP 48: 543-548.

Gladstone, J.S. 1918. A note on the structure of the feather. Ibis (Ser.10) 6: 243-247.

Harrap, B.S. and E.F. Woods 1964. Soluble derivatives of feather keratin. 1. Isolation, fractionation and amino acid composition. Biochem. J. 92: 8-18

Harrap, B.S. and E.F. Woods 1967. Species differences in the proteins of feathers. Comp. Biochem. Physiol. 20: 449-460.

Horton, N. 1990. Distinguishing between ducks, geeese and swans by means of feather micro-biometrics. 20th meeting BSCE, Helsinki, WP 32: 327-338.

ICAO 1978. Bird control and reduction. Airport Service Manual Part 3 (Doc. 9137-AN/898/2).

Lyster, I.H.J. 1985. A scanning electron microscope study of primary feather barbs. Acta XVIII Congr. Int. Ornithol., Moscow, 2: 1136-1137.

Ouellet, H. and S.A. van Zyll de Jong 1990. Feather identification by means of keratin protein electrophoresis. 20th meeting BSCE, Helsinki, WP 8: 53-71.

Perremans, K. 1990. External surface structures of rachis, rami and rachidial barbules of feathers and their potential for determination purposes. 20th meeting BSCE, Helsinki, WP 3: 21-30.

Perremans, K., A. De Bont and F. Ollevier in press. A study of featherprints by scanning electron microscopy. The Belgian Journal of Zoology.

Rutschke, E. 1960. Untersuchungen über die Wasserfestigkeit und Struktur des Gefieders von Schwimmvögeln. Zool. Jb. 87: 441-506.

Rutschke, E. 1966. Untersuchungen über die Feinstruktur des Schaftes der Vogelfeder. Zool. Jb. 93: 223-288.

Swales, M.K. 1970. A preliminary study on the application of the internal structure of feather barbs to avian taxonomy. Ostrich Suppl. 8: 55-66.

TABLE 1. Featherprint formulae of birds where site IX has very small pits and cell boundaries of type 6; FF=finely frayed, RF=roughly frayed, VRF=very roughly frayed, b, d, and f=micropapillae with concentrations b, d and f.

site / species	I	II	III	IV	V	VI	VII	VIII
Oystercatcher *Haematopus ostralegus*	VRF	VRF	VRF	RF	FF	VRF	VRF	VRF
Stone Curlew *Burhinus oedicnemus*	b	b	b	b	FF	FF	d	FF
Collared Pratincole *Glareola pratincola*	d	VRF	VRF	RF	FF	RF	FF	FF
Temminck's Courser *Cursorius temminckii*	FF	FF	FF	RF	FF	FF	FF	FF
Egyptian Plover *Pluvianus aegypticus*	f	FF	FF	FF	FF	FF	FF	FF
Golden Plover *Pluvialis apricaria*	f	VRF	VRF	VRF	FF	VRF	VRF	VRF
Herring Gull *Larus argentatus*	VRF	VRF	VRF	VRF	FF	VRF	VRF	RF
Kittiwake *Rissa tridactyla*	VRF+M	VRF	VRF	VRF	FF	VRF	VRF	VRF
Common Tern *Sterna hirundo*	d	RF	FF	FF	FF	VRF	RF	FF
Razorbill *Alca torda*	RF	RF	RF	RF	FF	VRF	VRF	RF

TABLE 2. Featherprint formulae of birds where site IX has very small pits and cell boundaries of type 1; VRF+M=very roughly frayed in the presence of a few micropapillae; for symbols see Table 1.

site / species	I	II	III	IV	V	VI	VII	VIII
Senegal Thick-Knee *Burhinus senegalensis*	b	b	b	b	FF	RF	FF	FF
Greenshank *Tringa nebularia*	FF	VRF	FF	RF	FF	VRF	FF	FF
Whimbrel *Numenius phaeopus*	b	b	b	b	FF	d	VRF	VRF
Snipe *Gallinago gallinago*	b	b	b	b	FF	d	RF	RF
Ruff *Philomachus pugnax*	FF	RF	RF	FF	FF	RF	FF	FF
Black-tailed Godwit *Limosa limosa*	d	RF	RF	RF	FF	RF	RF	RF
Great Skua *Stercorarius skua*	FF	FF	VRF	RF	FF	RF	RF	RF

TABLE 3. Featherprint formulae where site IX has deep pits and cell boundaries of type 6 with c=micropapillae with concentration c, RF+M=roughly frayed in the presence of a few micropapillae; for symbols see Table 1.

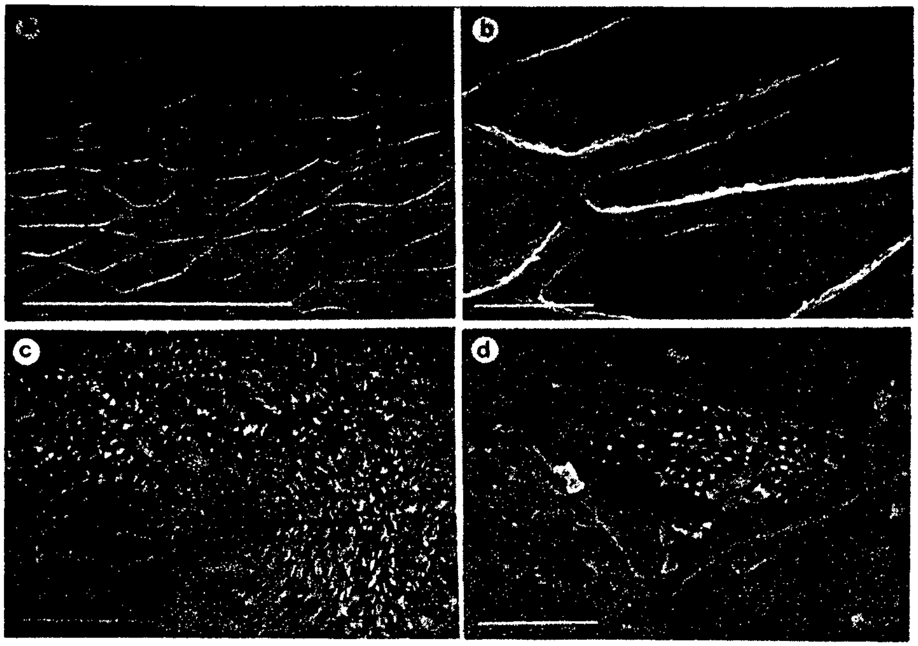
site / species	I	II	III	IV	V	VI	VII	VIII
Wattled Jacana *Jacana jacana*	FF	FF	FF	FF	FF	FF	FF	FF
Black-winged Pratincole *Glareola nordmanni*	c	RF+M	RF	RF	FF	RF	RF	FF
Brown-chested Lapwing *Vanellus superciliosus*	d	VRF	d	RF	FF	RF	RF	VRF
Lapwing *Vanellus vanellus*	d	RF	RF	RF	FF	RF	RF	FF
Green Sandpiper *Tringa ochropus*	FF	RF	RF	RF	FF	VRF	VRF	FF
Great Snipe *Gallinago media*	b	b	b	b	FF	f	RF	FF
Dunlin *Calidris alpina*	FF	RF	RF	VRF	FF	VRF	VRF	FF
Common Sandpiper *Actitis hypoleucos*	FF	RF	RF	RF	FF	RF	RF	FF
Woodcock *Scolopax rusticola*	c	c	c	c	FF	RF	RF	RF
Common Gull *Larus canus*	VRF	VRF	VRF	RF	FF	VRF	VRF	RF

TABLE 4. Featherprint formulae of birds where site IX has deep pits and cell boundaries of type 1 with 3 or 6=cell boundaries of type 3 (thick, rising lines) or of type 6 (no cell boundaries visible); for symbols see Table 1.

site / species	I	II	III	IV	V	VI	VII	VIII
Painted Snipe *Rostratula benghalensis*	FF	RF	RF	RF	FF	FF	FF	FF
African Black Oystercatcher *Haematopus moquini*	c	d	d	c	FF	RF	RF	VRF
Black-winged Stilt *Himantopus himantopus*	c	VRF+M	VRF+M	VRF+M	FF	RF	VRF	FF
Water Thick-Knee *Burhinus vermiculatus*	b	b	b	b	FF	FF	FF	FF
Grey Pratincole *Glareola cinerea*	f	RF	RF	RF	FF	FF	FF	FF
Rock Pratincole *Glareola nuchalis*	d	FF	FF	FF	FF	RF	FF	FF
Three-banded Plover *Charadrius tricollaris*	FF3	RF3	RF3	RF3	FF6	RF3	RF3	FF6
White-fronted Plover *Charadrius marginatus*	FF	RF	RF	VRF	FF	VRF	VRF	FF
Caspian Plover *Charadrius asiaticus*	RF+M	RF	RF	RF	FF	VRF	RF	FF
Ringed Plover *Charadrius hiaticula*	FF	RF	RF	FF	FF	VRF	VRF	RF
Little Ringed Plover *Charadrius dubius*	f	RF	RF	RF	FF	RF	RF	FF
Kittlitz's Plover *Charadrius pecuarius*	RF	RF	RF	RF	FF	VRF	RF	VRF
Forbes' Plover *Charadrius forbesi*	FF	RF	RF	RF	FF	RF	RF	RF
Grey Plover *Pluvialis squatarola*	FF	VRF	RF	RF	FF	VRF	VRF	VRF
Lesser Black-winged Lapwing *Vanellus lugubris*	c	VRF	RF	RF	FF	VRF	VRF	FF
Crowned Lapwing *Vanellus coronatus*	d	VRF	VRF	RF	FF	VRF	VRF	VRF

Spur-winged Lapwing *Vanellus spinosus*	f	FF	f	FF	FF	RF	RF	RF
African Wattled Lapwing *Vanellus senegallus*	c	RF	d	RF	FF	RF	RF	FF
Long-toed Lapwing *Vanellus crassirostris*	FF3	RF3	RF3	RF3	FF6	RF6	RF3	FF6
Marsh Sandpiper *Tringa stagnatilis*	FF	VRF	RF	RF	FF	RF	RF	FF
Redshank *Tringa totanus*	FF3	RF3	RF3	RF3	FF6	RF3	RF3	FF6
Wood Sandpiper *Tringa glareola*	FF	VRF	RF	VRF	FF	VRF	VRF	FF
Turnstone *Arenaria interpres*	FF	VRF	VRF	RF	FF	VRF	VRF	VRF
Curlew Sandpiper *Calidris ferruginea*	FF	RF	FF	RF	FF	RF	RF	FF
Little Stint *Calidris minuta*	RF	RF	RF	RF	FF	VRF	VRF	FF
Sanderling *Calidris alba*	FF	VRF	RF	RF	FF	VRF	VRF	RF
Grey-headed Gull *Larus cirrocephalus*	b	RF+M	RF+M	RF	FF	VRF	VRF	FF
Kelp Gull *Larus dominicanus*	RF	RF	VRF	VRF	FF	RF	VRF	VRF
Black-headed Gull *Larus ridibundus*	b	VRF+M	VRF+M	VRF+M	FF	VRF	VRF	FF
Sandwich Tern *Sterna sandvicensis*	FF	RF	FF	FF	FF	FF	FF	FF
White-winged Black Tern *Chlidonias leucopterus*	FF	RF	VRF	VRF	FF	VRF	VRF	FF
Guillemot *Uria aalge*	FF	RF	RF	VRF	FF	VRF	RF	FF
Little Auk *Alle alle*	VRF	VRF	VRF	VRF	FF	VRF	VRF	FF
Puffin *Fratercula arctica*	RF	RF	RF	RF	FF	RF	RF	RF

FIGURE 1.a: Southern Pochard: site I finely frayed with cell boundaries of type 5. Bar=100μm; b: Southern Pochard: site I more in detail. Bar=10μm; c: Greylag Goose: site I micropapillae of density b with cell boundaries of type 1. Bar=10μm; d: Mute Swan: site I micropapillae of density c with cell boundaries of type 5. Bar=10μm.



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Jerusalem, 23-27 March
1990

A TRIAL TO ESTABLISH IF OBSERVATION OF BIRD ACTIVITY IN THE UK USING AIRFIELD RADARS CAN PROVIDE A MEASURE OF THE BIRD HAZARD

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ABSTRACT

Military aircraft operating in the UK low flying system often suffer substantial birdstrike damage. It is possible that a radar-based bird hazard warning system, similar to those employed by other European nations, may be able to identify days on which a particularly high birdstrike risk occurs in the UK. This report describes a trial to determine if bird activity can be observed in the UK lower airspace using a number of airfield radars. The degree of correlation between the radar observation data and the birdstrike statistics during the same period is a measure of the potential effectiveness of a active bird hazard warning system.

A TRIAL TO ESTABLISH IF BIRD ACTIVITY IN THE UK CAN BE OBSERVED ON AIRFIELD RADAR SYSTEMS TO PROVIDE A MEASURE OF THE BIRD HAZARD

1. BACKGROUND

1.1 Analysis of birdstrike data shows that the bird hazard to military flying in the UK mostly affects those aircraft with a low flying role. Over 90% of all RAF birdstrikes take place at heights below 2,000 ft and approximately 70% of these occur outside the influence of airfield bird control. There is also a seasonal variation in the relative bird hazard due to the variation in species, population and activity of the birds which are resident during the different periods of the year. In particular, there tends to be an increase in the number of serious birdstrikes during the Spring and Autumn migration. During 1990, some 450 birdstrikes took place in the UK system resulting in damage to 205 aircraft. Whilst the general bird hazard for each month of the year is well documented, there is a requirement for a more precise system to detect those days on which intensive bird activity takes place. Timely bird hazard warnings can then be provided to aircrew.

1.2 Although ornithologists in the UK during the 1950s were some of the first to use radar to study bird movement, in contrast to other European nations, this technique has never been employed to measure and report the relative birdstrike risk. It has always been considered that the UK, which is located at the end and beginning of the migration routes to Scandinavia and North Africa, has a diffused bird movement which could not easily be observed.

1.3 During the Autumn migration in 1990, a RNLAF camera was fitted to a console of an air defence in East Anglia to record the bird migration between Holland and the UK. Although, for technical reasons, only a snapshot of the migration was recorded, there was sufficient data to conclude that the UK does experience periods of intense movement of birds similar to that observed on the Continent. The next step was to ascertain whether established radars in the UK could observe intensive bird activity and to evaluate the potential of the radars to form part of a bird hazard warning system. The trial commenced on 1st March 1991, using airfield radars at 26 locations grouped in 6 geographic regions and will continue until 31st March 1992 so that data from 2 Spring and 1 Autumn migrations will have been obtained. This paper provides an analysis of the results obtained from the airfield radar bird observation trial between March and November 1991.

2. OUTLINE OF THE TRIAL

2.1 The 26 nominated airfields were able to provide observations over a substantial area of England and Wales and some parts of Scotland. The Air Traffic Control Officers at each airfield was asked to log any bird activity that was observed on the search radar system and send a consolidated report of the observations to the Inspectorate of Flight Safety (IFS) at the end of each month. The monthly report was to include the date and time of the observation, location of the flock, direction of movement and a subjective judgement of the bird intensity on a scale of 1 to 3. A sample of the report form is attached at Figure 1. Each unit was issued with photographs of bird returns observed on Watchman and AR1 radars to assist in this task. The stations (with radar types) which participating in the trial are shown in Figure 2.

2.2 At IFS, the radar observation reports were entered into a database which also stored information on the number of RAF birdstrikes which took place in the UK. The two data sets were than compared to see if there was a correlation between them and, most importantly, whether such a correlation could have provided a measure of birdstrike risk warning. In essence, the trial consists of two discrete methods of sampling the bird density in the UK airspace each day; firstly by observing the bird activity on radar and, secondly, noting the number of birdstrikes - and thus the degree of bird hazard - that took place during normal flying operations.

2.3 From the encouragingly large number of radar observations recorded during the period 1 March 91 to 30 November 91, it has been possible to make some estimates of the performance of airfield radars types in detecting the various species of birds which are active in the UK during the Spring, Summer and Autumn months. It has also been possible to achieve an understanding of the procedures and equipment which would be required to develop a practical bird hazard warning system.

3. OVERALL RADAR PERFORMANCE IN DETECTING BIRDS

3.1 Radar Type. Prior to the start of the trial, advice was sought from a number of experienced air traffic control staff on the likely performance of airfield radars in detecting bird activity. It was generally believed that the processed-type display used on the Watchman and AR15 radars would probably exclude bird returns and it was therefore anticipated that the older ACR430 and AR1 would provide the majority of the observations. This proved not to be the case; the majority of reports came from Watchman equipped units although units with AR15 also performed well. However, the numbers of participating AR1 and ACR430 units

was much smaller than those equipped with the more modern radars and the poor performance of the obsolescent types may well have been a product of other factors such as serviceability and siting. A total of 198 reports were received by IFS and Figure 3 shows the number of observations which were reported for each radar type.

3.2 Serviceability. Periods of poor serviceability of some of the participating radars resulted in fewer bird observations than may otherwise have been expected. There were no observations units because of technical problems. In addition, the technical performance of the Watchman at one unit, which is well sited to observe bird activity in the Wash area, was substandard during the period.

3.3 Anomalous Propagation. Anomalous propagation (or ducting as it is often called) is caused be certain weather conditions and results in radar returns being received from many times the normal range of the radar equipment. Some units found difficulty in distinguishing bird returns from that of 'ana prop' and indeed, this problem was so severe in the area covered by Manston's AR1 that the unit could not confidently provide any observations.

3.4 Other Factors. There were clearly other factors which resulted in rather fewer observations from some units than would reasonably been expected. It was anticipated that those units sited near bird-attracting areas, such as coastlines and lakes etc, would have been in a better position to observe bird movement than some other sites. The results from Lossiemouth, Brawdy and Cottesmore proved this to be so. However, the lack of observations from equally well sited units was rather surprising.

4. RESULTS

4.1 Range. The ranges at which the bird targets were detected are illustrated in Figure 4. The average detection range for the Watchman radar was 6.7 nautical miles(nm) and 4.7nm in each case of the AR15 equipment. Although Watchman was able to detect some bird activity out to 25nm, 79% of the observations were less than 10nm The relatively short overall detection range is to be expected. The birds are generally confined to the lower levels - below 1500 feet - and present a small target to the radars. This perhaps self evident result does indicate the type of radar-based system which would be best suited to providing birdstrike hazard warnings. Such a system would consist of a number of small, strategically sited, short range radars to provide sampling of bird activity which would provide an interpolated measure of the birdstrike risk for areas within the U K Low Flying System.

4.2 Significant Days. It is possible to obtain a broad appreciation of the intrinsic bird hazard in the UK lower airspace during Spring, Summer and Autumn by analysing birdstrike statistics for each season. During Mar to May 91, there was a 88% chance that either one birdstrike or no birdstrikes would occur on any single working day. The 'one or no birdstrike days' may be considered to be the norm and the days on which 2 or more birdstrikes took place may have been associated with an increase in bird activity; such days can be considered significant in comparing birdstrike data with that from the radar observations. During the Summer - June to August 91 - the norm was 4 or less birdstrikes per day and in the Autumn it was 3 or less each day.

4.3 Spring (March to May 1991)

a. March March 91 marked the start of the trial and coincided with the Spring bird migration. Some units were able to commence observations from the beginning of March but delays in the postal system resulted in others not receiving the trial instructions until the end of the first week. Moreover, as a result of the Gulf Crisis, there were fewer low level sorties flown in the UK during March 1991. This doubtlessly resulted in fewer birdstrike. Nevertheless, there was a strong correlation between the significant days and those days when a high number of observations took place. The graph at Figure 5 shows this correlation clearly, the peaks representing periods of increased birdstrike risk. There were 2 such peaks during March; a large period of activity on the 13 and 14 March and a medium peak between the 19 to 22 March.

b. April. The level of low flying activity was quite high during April 1991 although there were fewer birdstrikes than during the previous month. Nevertheless, a correlation again existed between the birdstrike data and the radar observations, although it was not as marked as that of March. The results, at Figure 5 show that there were 4 peaks of activity which took place on the 10, 16, 24 and 29 April.

c. May 91. The Spring migration was complete by the end of Apr and the number of radar observations during May was substantially lower than the previous 2 Months as shown on the graph at Figure 6. This may be attributed to the size of the bird species - and their associated radar reflectivity - which are predominately active during the Summer in the UK. The smaller birds - such as swifts, swallows, house martins etc - are particularly active and, later in the Summer, the fledglings take to the air. Unfortunately, there was little information on the birdstrike reports to confirm

that the aircraft were colliding with these 'stealth' species. However, in most cases, the aircraft suffered either slight or no damage, an indication of low impact energy and therefore a low bird-weight. There was only one occasion - 8 May - when there was a correlation between birdstrikes and observations. On that day, a total of 5 observations were made in North Scotland, the East Midlands, West Midlands and the West; the 2 birdstrikes were discovered after flight.

4.4 Summer (June to August 1991)

a. June There was very little fit between the occurrences of birdstrikes during June and the very few radar observations that were reported (See Figure 6). Again, the smaller species of birds seemed to be responsible for the majority of birdstrikes; this was indicated by the high proportion of 'no damage ' incidents which took place during the month.

b. July The correlation between the few radar observations that took place in July and the large number of birdstrikes is inconclusive. Only on one day, 8th July, was there more than one radar observation. On this occasion the 3 observations were reported from the East Midlands and East Anglia areas. One birdstrike on that day was at the airfield where one of units that reported an observation is sited.

c. August There was no discernable correlation between birdstrikes and radar observations during August 1991.

4.5 Autumn (September to November 1991)

a. September The weather during September 1991 was unusually hot and this may have delayed the start of the Autumn migration. There was little evidence of large scale movement of birds on radar and birdstrikes damage during the month suggested that the smaller species birds were involved. Three radar observations occurred on 18th September. These were all reported by the same unit and was probably due to a local phenomenon.

b October There was a sharp rise in the number of radar observations in the latter half of October 1991 indicating perhaps strong migration activity - there was at least one observation reported on each working day from 15th to the end of the month. However, unlike March 1991, there was no clear correlation between the birdstrikes and the observations

c November The relatively high number of radar observations continued into November 1991 with only a small decline towards the end of the month. Again, there was no positive correlation between birdstrikes and radar observations - Figure 9 referrs.

4.6 Intensity. Paragraph 2.1 described the method used for reporting the intensity of bird activity for each radar observation. Although, subjective judgement by the radar operators is a rather crude and highly criticised technique, 28 of the 43 days on which at least one intensity '3' was reported also coincided with a birdstrike peak. Moreover, the coincidence of intensity 3 were most marked during March, April and early May and again in late October.

4.7 Time of Observations. The time that observations are made is an important parameter in any potential bird hazard warning system. If the observations tend to occur during the latter part of the day, it would be quite impossible for a bird hazard warning to be issued to aircrew engaged on early morning sorties. The graph at Figure 10 shows the number of observations that were made for each 2 hour period from 0600 hours to 2200 hours; the first column represents the observations which took place between midnight and 0600 hours. There were no observations between 2200 hours and midnight. It can be seen that the observations were biased towards the morning to early afternoon period with 42% taking place prior to 1000 hours. The observations occurring between 0600 and 0800 hours (20%) may be associated with bird activity during the dawn period.

5. **SUMMARY**

5.1 A total of 198 radar observations of bird movement were reported between 1st March and 30th November 1991 from the 26 units which are participating in the IFS airfield radar bird activity observation trial. The following points summarise the analysis of the reports that were received during this period:

a. Of the 26 participating units, 15 submitted one or more reports during the period. It would seems that there are a number of factors other than technical performance, such as siting and serviceability, which influence the ability of airfield radars to detect bird activity.

b. Watchman and AR15 equipment which have processed displays demonstrated a good ability to observe bird movement. Of the older radars with unprocessed displays, 2 observations were reported from a ACR 430 unit but the AR1 did not detect any bird activity during the period.

c. Many of the radar returns from bird-type targets would have been suppressed by display processing. It is therefore likely that the potential number of bird observations which could be extracted from the pre-processed signal would be far greater than that reported by the operators.

d. The average range of detection of bird activity was 6.1nm. The Watchman radar demonstrated a slightly superior range to that of the AR15.

e. Birdstrike and radar observation reports were examined for correlation between the data sets. During the first part of the period, the strongest correlation took place in March corresponding to the Spring Migration. A good correlation took place in Apr and progressively poorer correlations occurred during the Summer. The reverse of this trend occurred in the second half of the period although the Autumn did not provide any strong correlation.

f. The degree of correlation between birdstrike and radar observation data is probably consistent with the bird species which are prevalent in the UK during March to November. The large migratory birds may be active during Spring and Autumn whilst the smaller birds - the 'stealth' species - become more abundant in the Summer months.

g. The reported intensity of each bird flock was based on the subjective judgement of the radar operator on a scale of 1 to 3. There was a reasonable coincidence between reports containing intensity '3' and those days on which both a high number of birdstrikes and radar observations took place.

h. Radar observations took place at various times of the day from 0315hrs to 2045hrs. However, most took place from early morning to early afternoon.

IFS(RAF), MOD London February 1992

List of Figures:

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2. Location of Participating Radar Units
3. Number of Observations by Radar Type
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5. Radar Observations and Birdstrikes - Mar and April 91
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9. Radar Observations and Birdstrikes - November 91
10. Distribution of Time of Radar Observations

D/IFS(RAF)/115/10/4/2

IFS AIRFIELD RADAR BIRD OBSERVATION TRIAL

TO: FS2c(RAF)
Inspectorate of Flight Safety
Ministry of Defence
Adastral House
Theobalds Road
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MONTHLY RETURN OF BIRD ACTIVITY OBSERVED BY RADAR

Unit: RAF BRAWDY   Radar Type WATCHMAN

Month JUL 91

Date	Time	Location	Direction	Intensity	Remarks
15 JUL	0935	160°/06	SE	LIGHT	
17 JUL	0619	240°/10	SW	HEAVY	
24 JUL	1017	140°/10	E	MEDIUM	

Note 1: Direction of movement of observed intensity in degrees true
Note 2: Give location of centre of bird intensity as distance (nm)/degrees true from airfield

Figure 1

RADAR BIRD OBSERVATION TRIAL 1991
LOCATION OF RADAR UNITS

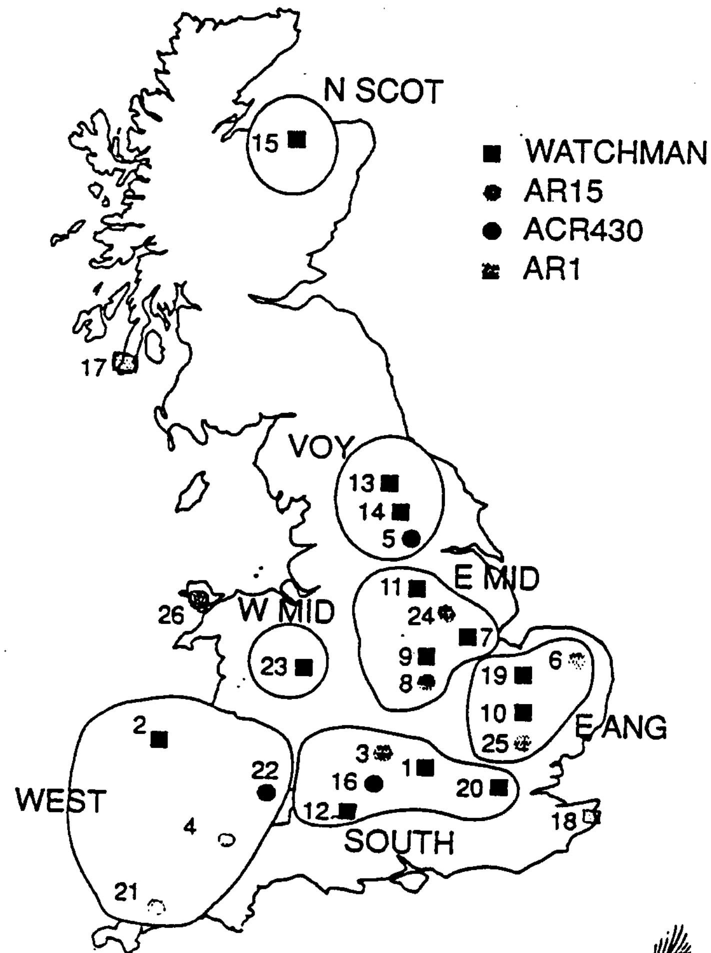
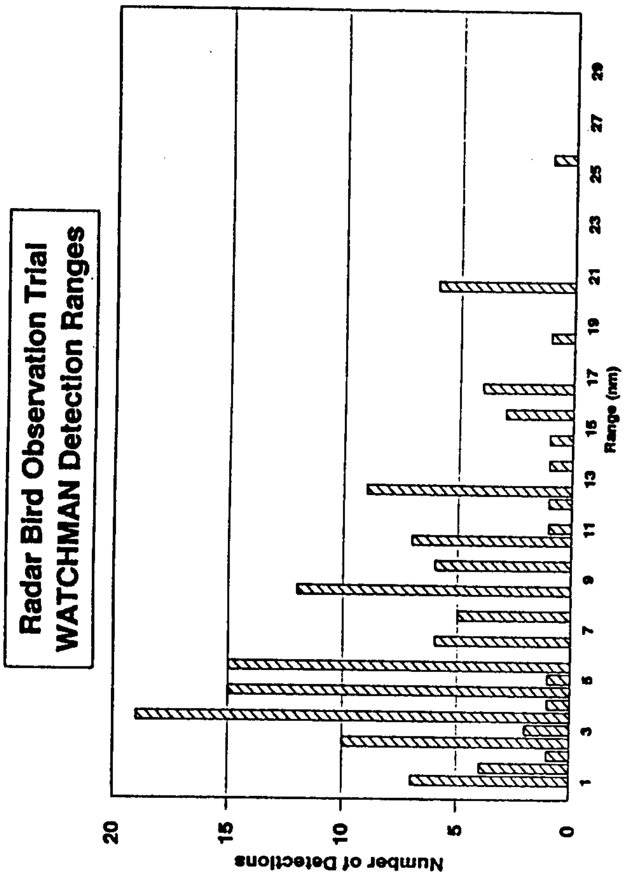


Figure 2



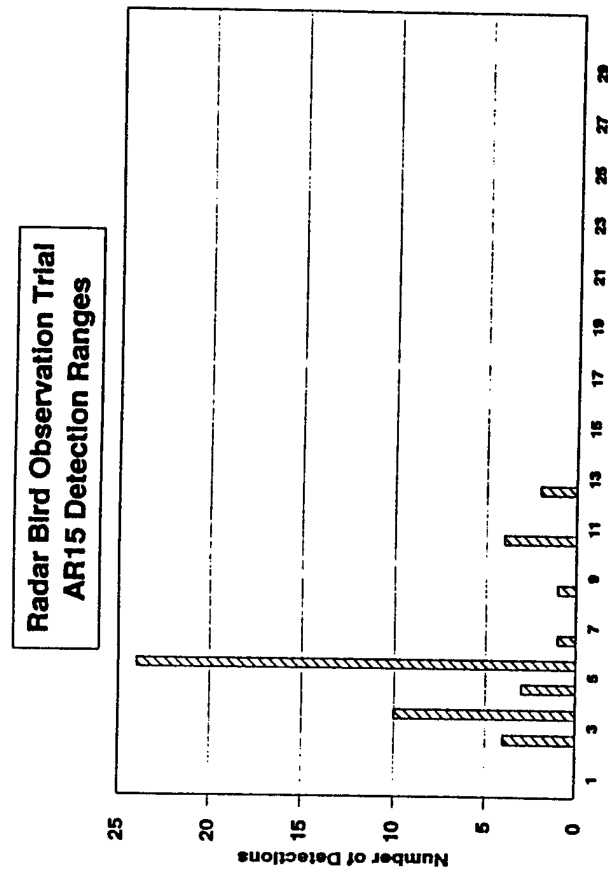


Figure 4

SUMMARY OF RESULTS
Number of Observations By Radar Types

	Watchman	AR15	ACR430	AR1	Total
March	23	13	0	0	36
April	37	13	0	0	50
May	10	4	0	0	14
June	5	2	0	0	7
July	8	3	0	0	11
August	8	4	0	0	12
September	5	2	0	0	7
October	25	5	1	0	31
November	22	7	1	0	30

TOTAL 198

Figure 3

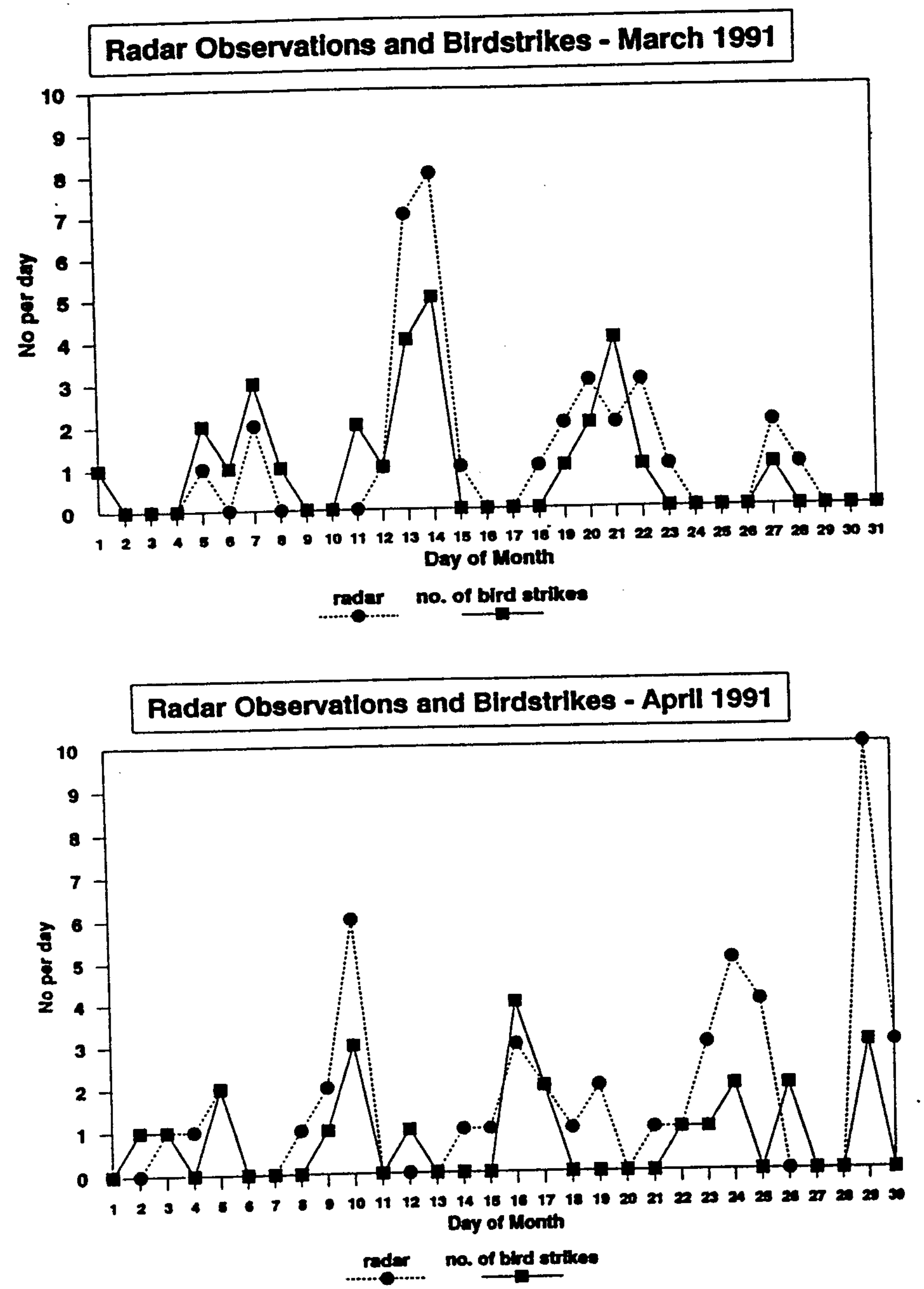


Figure 5

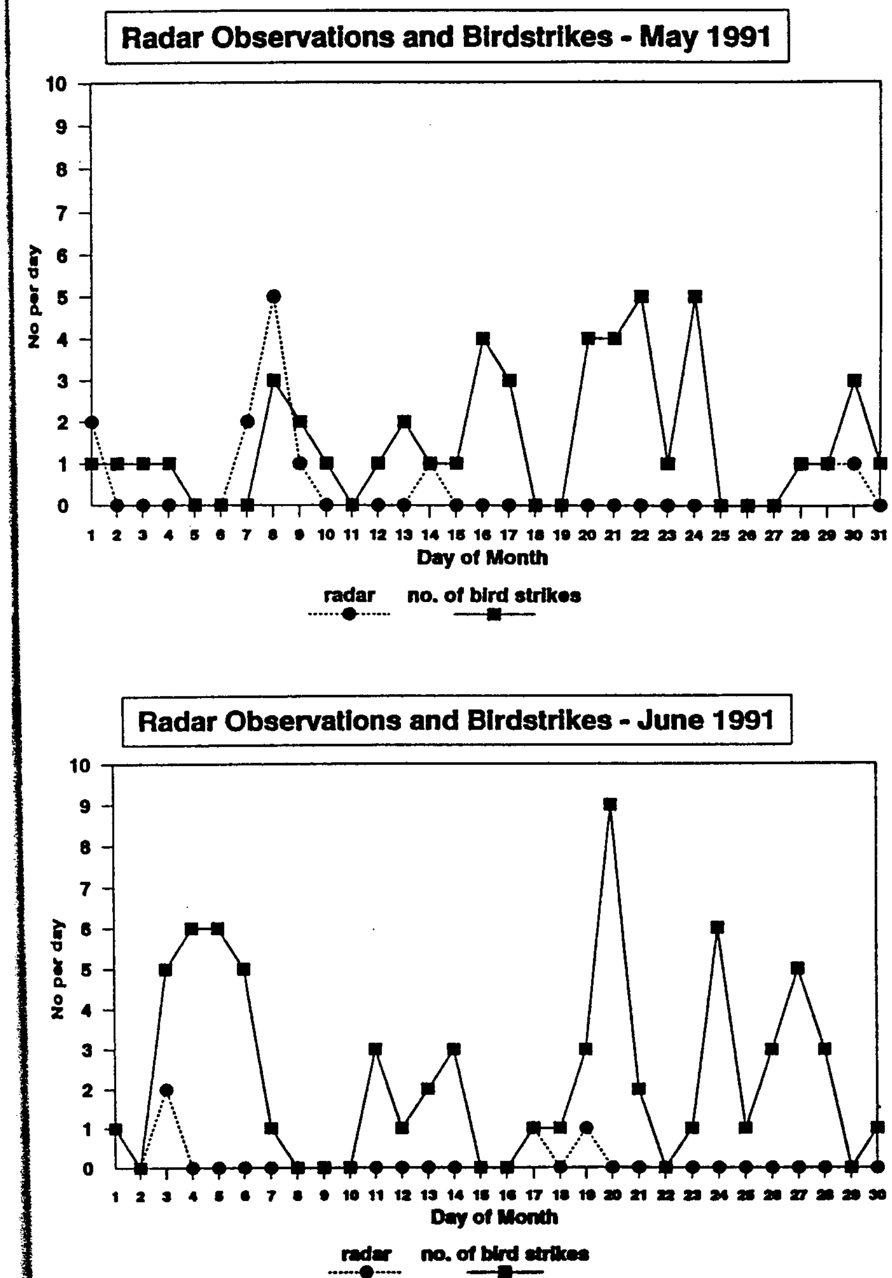


Figure 6

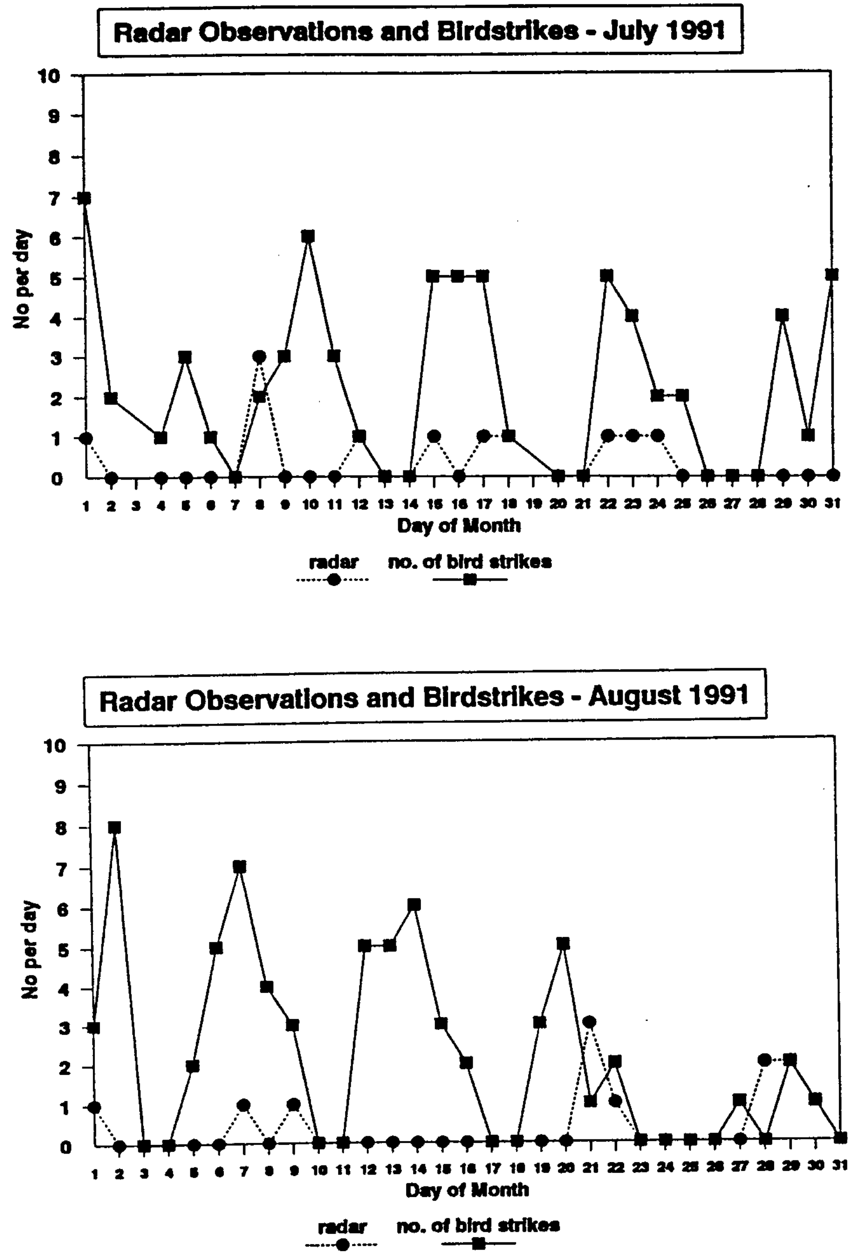


Figure 7

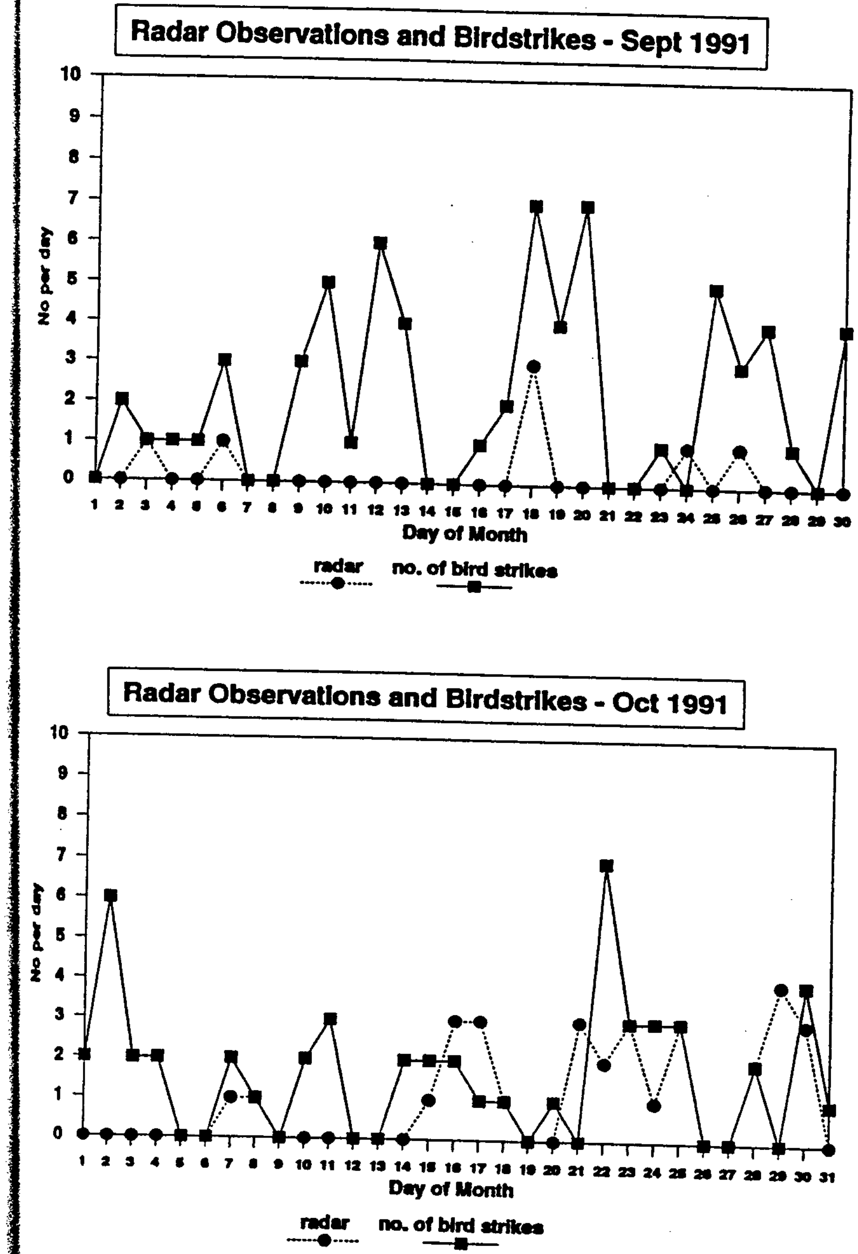


Figure 8

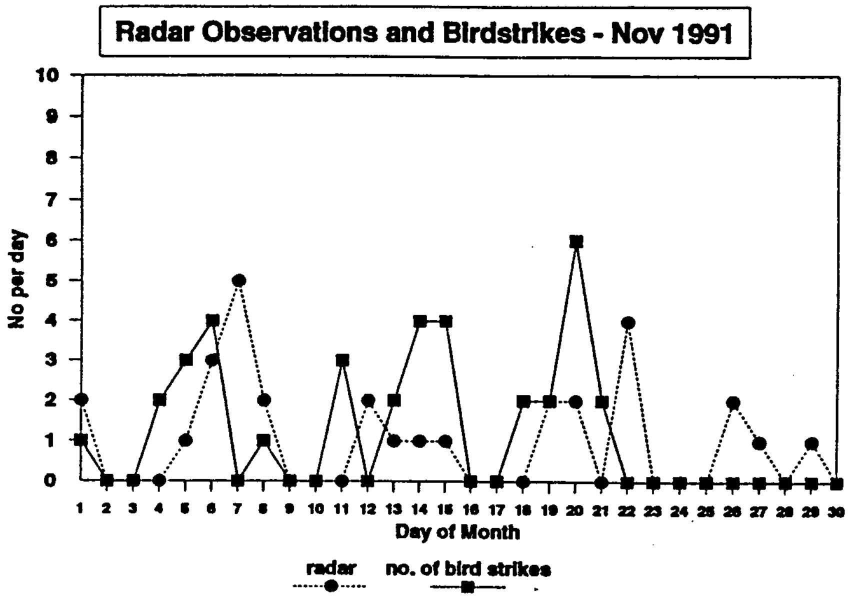


Figure 9

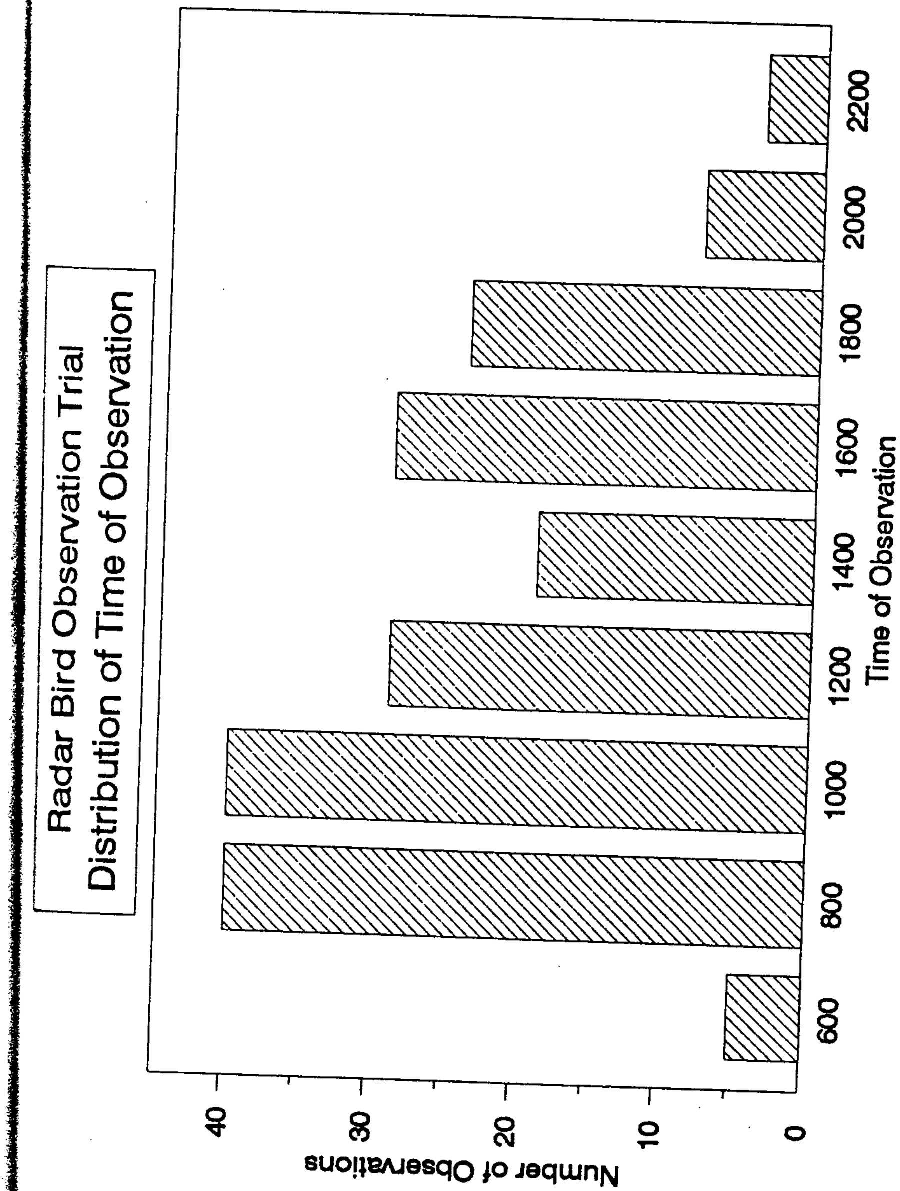


Figure 10

FIVE METHODS FOR STUDYING NOCTURNAL BIRD MIGRATION OVER ISRAEL

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Israel is a land bridge between three continents and a major crossroads for birds migrating from Europe and Asia, to Africa and back twice yearly, during spring and autumn. Most birds migrating over Israel (280 species) do so mainly at night.

Nocturnal migration rates and times over Israel were first studied in 1989, with an ASR-8 scanning radar. Since then, five different methods for tracking migration have been tried: direct observations, listening to calls, radar, night flights and indirect data from aircraft bird strikes. Radar tracking has been found to be the most efficient method.

Three years of research have shown that there is a regular pattern in times and rates of nocturnal migration. Radar data has shown that on peak migration nights a million birds fly over Israel in one night.

During these three years it was found that the correlation between the migration rate during the first three hours of the night and the total rate for that night makes statistically significant predictions of the expected migration rate possible.

1. INTRODUCTION

About 280 bird species migrate over Israel, mainly at night. Diurnal migration of soaring birds over Israel -- raptors, storks and pelicans -- has been thoroughly studied with radar, ground observers and motorised glider (Leshem, 1984, 1988, 1991). Most of the damage done to Israel Air Force aircraft is attributed to these birds. This is due mainly to their large size and their flight altitude, which can reach 5000 ft. above sea level.

Nocturnal migration, on the other hand, occurs mainly at altitudes up to 4000 ft. and is far greater, by at least one order of magnitude. The probability of collisions with these birds is thus much higher.

The importance of fighter plane night flights has been emphasized by the Gulf War. Most Air Forces in the world will probably increase the number of nocturnal training hours in the future. With improved technology solving problems of night vision, nocturnal aerial skirmishes will practically become "day skirmishes". The flight altitude at night has decreased, so that aircraft are now exposed to significantly greater masses of migrating birds. In order to prevent the heavy damage which may occur during these night flights the distribution of nocturnal migration in time and space must be studied.

As a result of objective difficulties in tracking nocturnal bird migration the subject has remained in the "dark" in many parts of the world. Several studies using different methods on the subject have been carried out (Bruderer, 1981; Buurma, 1988; Buurma and Bruderer, 1989).

In Israel, a combination of five different methods were used to follow nocturnal migration, with varying amounts of success: direct observations, bird call tracking, night flights with light aircraft to count and identify individual species, radar and indirect data gleaned from the number of bird–aircraft collisions at night. Radar tracking was found to be the most efficient method, but the five methods complement each other, and none can be of use by itself.

Radar tracking has enabled study of nocturnal migration distribution in time and space. Comparison of results from the years 1989–1991 indicates a regular pattern of migration times and rates in different seasons. Light aircraft equipped with a projector has provided estimates of the numbers of birds migrating at night over Israel, and made quantification of radar data possible.

A statistically significant correlation between the rate of migration during the first three hours of the night and the total rate for that night has been found. This has allowed predictions on the total rate of migration each night to be made. More that 20 different species have been definitely identified by calls and direct observations in the moonlight.

2. METHODS

Surveillance radar – The radar used in this study was an ASR–8 surveillance radar, beam width 35° /4.8°, 10 (cm), used for air traffic control at Ben–Gurion International Airport, Tel–Aviv. Nocturnal migration for a radius of 20 miles can be seen on the radar screen.

The radar screen was photographed with a Nikon reflex camera, diaphragm opening 4.5, continuous exposure of 10 minutes for each still photograph. Photographs were taken once every 1/2 hour during the night in spring and autumn. Control photographs were taken during the day at 0900, 1200 and 1500 hours, using the same method (Alfiya, 1990).

Magnitude of migration was determined by the rate of flashes received from migrating birds on the radar screen photographs. A scale of 5 migration magnitude levels was established and the rate of migration during each hour of the night determined accordingly. The levels were: 1 – no migration, 2 – weak migration, 3 – medium migration, 4 – heavy migration, 5 – very heavy migration.

This radar makes it possible to study migration speed and direction over a relatively large range. Its drawbacks are the inability to measure migration altitude, determine bird species or exact numbers of migrating birds. The data received is limited to the area covered by the radar, and when conditions are cloudy, the birds cannot be seen since the screen is covered with clouds.

Light aircraft – A Cessna airplane, equipped with a projector and with lit landing lights, flew at a right angle to the migrating birds, across Israel from east to west, along 10 km. During each flight 1 million cubic meters of air were scanned for 5 minutes. The flights took place when radar showed migration magnitudes of 5. Flights were held at altitudes of 1000, 1500, 2000, 2500 and 3500 feet, and the number of birds seen recorded. This method made it possible to estimate the number of birds migrating over Israel in magnitudes 1-5, and to receive quantitative estimates of the radar data. Its main disadvantages are the high cost of flight hours and the inability to identify the bird species because of the short time in which it passes through the light beam (about 1/10 second).

Direct observations – An observer using a Kowa telescope with 45x magnification watched the moon. Birds passing between the observer and the moon can be seen for a short period of 1/10 second. Identification is made from the silhouette or flight style. A thermal image camera (Mini Flare, Israel) was used similarly. These methods require many observation hours and very experienced personnel, and even so up to 50% of the birds can remain unidentified. The principal advantage of this method is that in many cases it makes identification of the bird species or genus possible.

Bird call tracking – This included direct listening with no instruments and tracking with amplifiying instruments, making it possible to identify some of the migrating species. This method is effective only for those birds which use calls while migrating, requires many hours and great experience and expertise. Its main advantage lies in the positive identification of the bird genus or species.

Bird–aircraft collisions – This method can provide indirect data on the location of birds in time and space. In many cases it is also possible to identify the bird species from feather remains. Its drawback lies in the fact that it reflects mainly the activity of the sampling instrument – the aircraft involved in the collision.

3. RESULTS AND DISCUSSION

Times of night migration in Israel – The results of three years of following nocturnal migration show that migration times follow a regular pattern. Table A presents data on migration times in spring and autumn. The beginning of the season was determined according to the first night with magnitude 2 migration. In the same manner, the end of the season was determined by the last night with migration magnitude ≥ 2.

Table A – Nocturnal migration times in spring and autumn 1989–1991*.

Season	Start of migration	End of migration	Remarks
Spring '89	-	21/5	Partial data
Autumn '89	17/8	-	Partial data
Spring '90	8/3	16/5	
Autumn '90	15/8	21/11	
Spring '91	19/3	20/5	
Autumn '91	19/8	21/11	

*End of season determined according to the last night with average migration magnitude 2.
*Beginning of season determined according to first night with average migration magnitude 2.

Cloudiness sometime prevented documentation of migration, which might mean that the real first or last night was missed. The magnitude of migration also followed a regular pattern, with average migration magnitude 2 during the first month, and 3.5 and 2.5 for the second and third month in autumn and spring respectively. In the final month of migration the average magnitude was 2.

Migration rate in the years 1989–1991 – The distribution of migration magnitude (levels 1–5) was examined during all the tracking hours (radar data). In table B we can clearly see that migration rate in autumn is higher on the average by 50% than in spring. This ratio was constant during the three years of this study. The same is true for the average migration rates each season.

Table B – Distribution of tracking hours according to migration magnitude
Comparison of nocturnal migration hours (%) according to migration magnitude levels (1989-1991).

Level / Season	1	2	3	4	5	Average migration magnitude degree - per hour of night in the season
Spring 1989 Partial data 13/4-30/5	35	33	23	7	2	2.08
Autumn 1989 Partial data 1/8-30/10	16	7	10	28	39	3.67
Spring 1990 Complete data 1/3/-30/5	30	25	21	17	7	2.46
Autumn 1990 Complete data 1/8-30/11	27	13	12	20	28	3.09
Spring 1991 Complete data 1/3-30/5	42	22	20	10	6	2.16
Autumn 1991 Complete data 18-30/11	29	10	15	21	26	3.08

Quantification of radar data – Night flights with light aircraft showed that during a 10–hour night with average migration magnitude 5, approximately a million birds pass over the skies of Israel. According to this standard, the significance of the radar photographs from Ben–Gurion is as follows: during a night with an average migration magnitude of 4, 0.75 million birds pass over in 10 hours, 0.5 million when the average migration magnitude is 3, 0.25 million when it is 2 and no birds at all when it is 1.

Prediction of migration magnitude degrees – One of the most valuable indicators for predicting the rate of migration during one night, is the correlation found between the migration rate during the first three hours of the night to the rate for the entire night. The coefficient of correlation is high and statistically significant (table C), providing a success rate of 80% in predicting the magnitude of migration at the beginning of the night for the rest of it.

Table C – Correlation between migration magnitude during the first three hours of the night to that during the rest of the night, 1989-1991.

Year	1989	1990		1991	
Season	spring	autumn	spring	autumn	spring
r	0.85	0.80	0.80	0.75	0.85
α<	0.001	0.0001	0.0001	0.0001	0.0001

Direct observations and tracking of night migrant calls –- Despite the low effectiveness of these methods 22 different species/genera were definitely identified migrating at night.

One of the objectives of this study is to compose a map of bird strike danger areas for Israel Air Force aircraft. This map will be based, among other factors, on the masses of birds found in the air at any given moment. In order to attain this objective it is necessary to know which species migrate at night and when they pass over. Ringing information could possibly be a source of reliable information which would complement the data from direct observations and bird call tracking.

The information we possess at present provides quite a clear picture of migration rates in time. Putting together the "puzzle" of the bird strike danger map necessitates data on the rate of migration in time (which we have), the weight of the migrating birds and the times they migrate (exists partially) and the distribution of migration in space – horizontally and vertically. The last component of this "puzzle" has been studied so far only from indirect data from bird–aircraft collisions, a method whose drawbacks have been discussed. In order to complete this information a pair of Furuno mobile radars have been recently purchased. These are marine radars which have been modified for bird tracking. The FR–1411 scanning radar and the FR–8100 altitude radar have been mounted on a vehicle and will perform as mobile laboratories to study migration, thus completing the picture on migration in space.

ACKNOWLEDGEMENTS

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REFERENCES

Adams, D.W.H. 1962. Radar observations of birds migration in Cyprus. Ibis 104:133–146.

Alfiya, H. 1989. The nocturnal migration of birds over Israel. The TORGOS 8(1): 22–26. (Hebrew, English summary)

Alfiya, H. 1990. Nocturnal migration of birds over Israel – changes in direction and rate of migration according to the time of the night. BSCE/WP: 83–92, Helsinki.

Bloch, R. & B. Bruderer 1982. The air speed of migrating birds and its relationship to the wind. Behav. ecol. Sociobio. 11: 13–24.

Bruderer, B. 1981. Status and aims of radar migration research in Switzerland. Rev. Suisse de Zool. T. 88(4): 855–864.

Buurma, L.S. 1988. Thermal imaging, a new remote sensing technique for nocturnal wildlife studies. BSCE/WP: 43, Madrid.

Buurma, L.S. & B. Bruderer 1989 (in press). The application of radar for bird strike prevention.

Eastwood, E. & G.C. Rider 1965. some radar mesurements of the altitude of bird flight. Br. Birds 58:396–426.

Hunt, F.R. 1975. Automatic radar equipment to determine bird strike probability. Part 1. Night–time passerine migration. National Research Council Canada, Field Note no. 69, April 1975, Ottawa.

Leshem, Y. 1984 Paths in the sky –– autumn migration of raptors. Teva Va'aretz 26(5):29–36. (in Hebrew)

Leshem, Y. 1988. Following soaring bird migration from the ground, motorized glider and radar at the junction of three continents. BSCE/WP 191–214, Madrid.

Leshem, Y. 1992. Fall and spring migration of soaring birds over Israel. PhD thesis, Tell–Aviv uni. (in Hebrew)

Mead, C. 1983 Bird migration. Country Life Books, England.

BSCE-21
Jerusalem, 1992 WP2

PREDICTING REGULARITY OF BIRD MIGRATION IN GLOBAL BOTTLENECK AREAS, ON A DAILY, SEASONAL AND YEARLY SCALE, AND ITS IMPLEMENTAION IN ISRAEL AIR FORCE AND CIVILLIAN FLIGHT.

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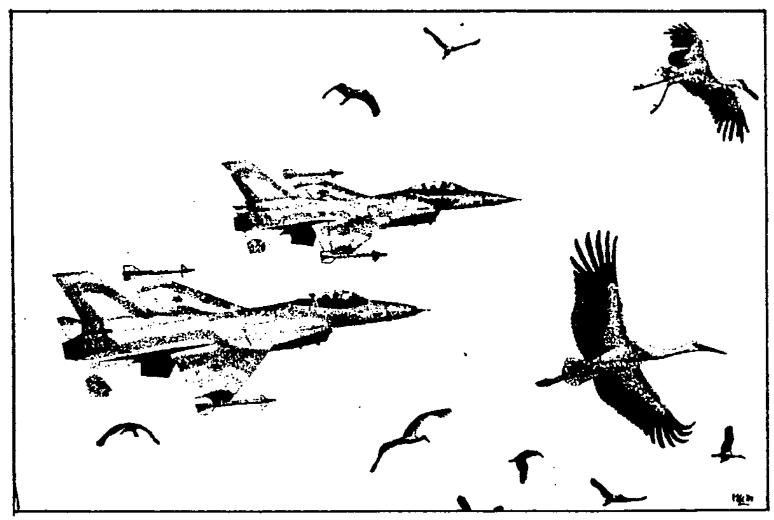
ABSTRACT

The strategic location of Israel, at the junction of three continents, makes it a "bottleneck" area into which significant portions of the world populations of soaring birds converge. This study used a combination of five different methods to gather data, with each method complementing and confirming the data from the others. The appearance times of migrating raptors and storks was found to be very precise (±3.5-±4.92 days). Variations in migration routes on a daily, seasonal and yearly scale were also found to be very regular. The results of this study have been implemented in the Israel Air Force and in the civillian flight system. Procedures for limiting flights during the migration seasons have reduced the average yearly damage to aircraft by 88% compared to the past, while permitting low altitude flights during days with light migration.



INTRODUCTION

Despite its small size, Israel is strategically located at the junction of three continents. As a result, Israel is a "bottleneck", into which all or a large part of the world populations of certain soaring species converge, during spring and autumn. The combination of its unique location and small size, facilitates studying a number of basic migration phenomena, which cannot be followed in breeding or wintering grounds. The only other similar site in the world is in Panama.

Although many migration surveys had been carried out before the early 1980's, there were still many gaps in the existing knowledge of the subject. The surveys had concentrated on a number of limited areas, using conventional optical equipment, so that only a fraction of migration was covered on a horizontal and vertical section. There was no systematic reference to the subject of climatic conditions and their influence on migration.

The concentration of an extremely large mass of soaring birds in the limited air space over Israel, creates a severe flight safety problem for Israel Air Force aircraft and their pilots. The analysis of damage caused by birds between 1972-1983 showed that hundreds of accidents had occurred. Many of these were serious (damage exceeding 1/2 million dollars), several aircraft crashed and one pilot was killed. 74% of the accidents occurred during migration months. Total losses reached tens of millions of dollars.

The objective of this study was to examine if any yearly or seasonal regularity exists in the numbers of birds passing over, times of passage and length of passage time over Israel. The possibility of regularity in daily and seasonal migration routes and altitudes was also checked as well as migration velocity. The influence of various climatic and biological factors on this system was studied. All this in order to examine the possibility of predicting changes and applying the conclusions of the study in the Israel Air Force, in order to avoid injury to pilots and save large amounts of money for the national security budget.

METHODS

Five different data gathering methods were used for this research:
1. <u>Ground Observer Network</u> - Dozens of studies have tracked migration with small numbers of observers at 2–3 key observation points. In this study, for the first time ever, ground observers were placed along a **broad front**: 25 observation points were placed across the country, along 75 kilometers, during several migration seasons. More than 150 experienced birdwatchers logged about 224,000 observation hours.
2. <u>Light Aircraft Tracking</u> – This method proved excellent for locating principal migration routes, their altitudes and counting flocks per time and distance units, and very efficient on "peak" migration days. Additional flights were carried out to confirm the radar distinctiom ability (see method 5). Twenty-nine flights totalling 83:40 hours were carried out.
3. <u>Motorised Glider</u> – This method enabled continous flying, up to 11.5 hours, with the same flock, as well as exact mapping of the migration route, altitude, flock progress rate, climbing and gliding in thermals. One hundred and seventy–three flights totalling about 720 hours were carried out. This was the first time motorised glider migration tracking was used in the Middle East. No study using a motorised glider to systematically follow migrating flocks for such long periods of time had been done up to now, both in the number of flight hours and the number of tracking days.

4. <u>Unmanned Aircraft (Drones)</u> - This method enabled tracking single flocks for about 150 kilometers with constant documentation of the flock by video camera. Nineteen flights were carried out. To the best of our knowledge, this is the first biological study ever to make use of this military instrument for research.
5. <u>Radar</u> – A radar screen at the Ben-Gurion International Airport surveillance radar was permanently available during the migration seasons. This enabled constant tracking during all hours of the day. The cloud radar of the Shaham Company followed migration regularly only during one season. Its use was terminated due to technical problems. A total of 8125 radar tracking hours were carried out. This is the first time radar was used to follow soaring bird migration in the Middle East in general, and in Israel specifically.

Most migration tracking research has been limited to one method, and only a minority combined two methods simultaneously, such as a combination of radar and ground observers (Evans & Lathbury, 1973) or light aircraft and radar (Pennycuick, Alerstam & Larsson, 1979). In our study, we have developed, for the first time, to the best of our knowledge, research based on a **<u>combination of five methods</u>** for data gathering from one migration system, with each method complementing, at least partially, the deficiencies of one of the others. At the same time this enabled confirmation of data gathered by one method by one of the other methods. The development of several parallell research methods allowed for integration between the various methods. The radar could, for example, take over from the motorised glider for a short period of time, to enable refuelling and rest; it could then direct the glider to the exact position of the flock it had left to continue tracking.

The statistical analysis in this research is based on 9 autumn migration seasons for raptors and 4 for storks and pelicans. During spring migration raptors were followed in Eilat for 6 years and storks for 4 in the western Negev.

RESULTS

Comparison of our results to data in the relevant literature, proves, that the data for species whose total population or most of it passes through "bottleneck" areas, provides relatively reliable estimates of **minimal population size**. The numbers counted during migration are sometimes higher by an **order of magnitude** than data from existing studies (Leshem,1991).

In order to examine long-term regularity in major migrating species appearance, the weighted average day of arrival was calculated for all the years of the study, as well as the date by which half of the population had passed by over Israel, the average peak day and the average arrival percentage for each species on the peak day. The results show that it is possible to predict the appearance days of various raptor species with a precision of±1.35 to±3.12 days in autumn and±1.92 to±4.92 days in spring ($P<0.001$). The arrival of storks can be predicted with a precisi on of±3.78 days in autumn and±5.46 days in spring. The rest of the data examined was found to be statistically significant, but for some the time span was broader. The conclusion reached was that it is possible to predict appearance times of the various species.

Comparison of arrival percentages on the peak day for a number of raptor species shows, that the passage percentages in autumn for flocking species are greater than for non-flocking species (17.1%–30.1% and 9.0%–15.6% respectively). In spring, the difference between flocking and non–flocking species is even greater: 27.7%–46.0% and 8.3%–12.0% respectively. Intra-specific

comparison shows, that for many of the species the arrival percentage on the peak day is higher in spring than in autumn. This is probably the adult population, hurrying to return to its breeding grounds in spring, therefore moving in more concentrated waves. Thus an inverse relation between the arrival percentage on the peak day and age of sexual maturity is found: 46% of the the Levant Sparrowhawk, population, which reaches sexual maturity in its first year, passes over during the peak day compared to 17.7% of the Steppe Eagle population, which reaches sexual maturity at age 5. In non-flocking species the situation is similar, although in less concentrated waves.

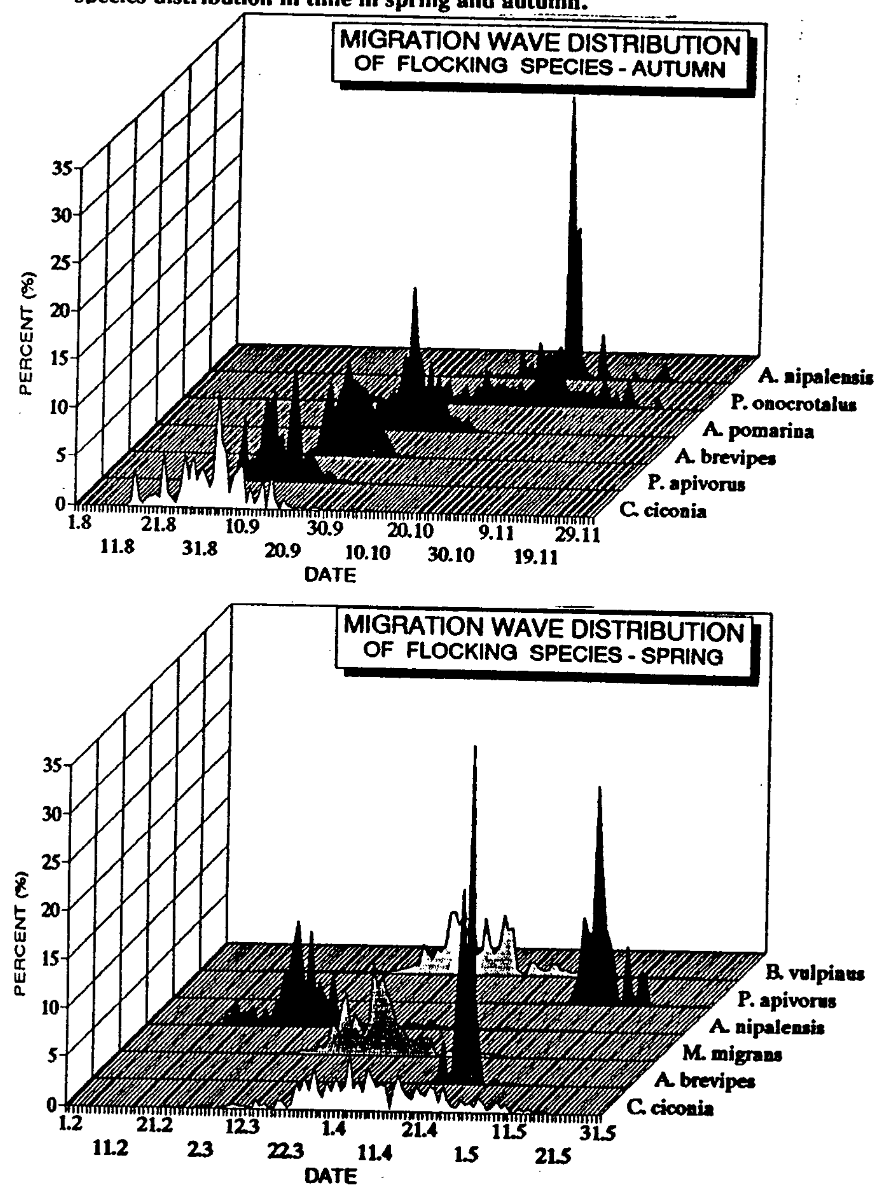
The regularity of passage time period length was examined for each of the species migrating over Israel. Analysis of the data shows, that those species flying over in large numbers tend to flock and pass over during the shortest time periods. Thus, 90% of the populations of the five species which flock in autumn, pass over during 13-20 days, compared to five non–flocking species which pass over during 24–35 days. The only exception to this rule is the White Pelican (Pelecanus onocrotalus), whose passage time period is long (114 days in autumn), despite it being a true flocker. The reason seems to be that this species flocks during the breeding season as well, populating very broad breeding grounds (between 22–85 longitude), with each breeding colony reaching its nesting sites as independent units. Accordingly, we find, that this is the only flocking species that has no peak days on which more than 10% of the population fly over, and whose weighted average day of arrival is the least statistically significant of all flocking species (12.39 days).

Despite all the above, in non-flocking species, which have a longer passage time period, the weighted average arrival day is very exact, within a span of 1.8 to 2.85 days only, in the 4 non-flocking species analysed in this study (Booted Eagle Hieraeetus pennatus, Short–toed Eagle Circaetus gallicus, Egyptian Vulture Neophron percnopterus and Marsh Harrier Circus aeruginosus). These four species also arrive with a high time overlap in autumn and spring, and there is a possibility that what we see here is inter–specific flocking of non–flocking species (they were also observed migrating in common thermals).
The spring migration wave is longer than the autumn one in most birds of prey and storks. In many of the species passage time in spring is almost double that in autumn.

Flocking and non–flocking species passing over Israel were compared according to their wintering grounds and type of food. The data shows, that all nine flocking species overflying Israel, migrate south of the Sahara and some of them reach South Africa. They feed at least partially on exothermic prey. Three of the 4 non–flocking species which are commoner: Booted Eagle, Egyptian Vulture and Short–toed Eagle also feed on heterothermic prey and migrate south of the Sahara. Only the Marsh Harrier is an "intermediary species", wintering both north and south of the Sahara, and feeding accordingly on birds and mammals. A number of species feeding on endothermic prey do not flock, and accordingly do not migrate south of the Sahara. This phenomenon is parallelled in New World raptors (Mindell, 1985).

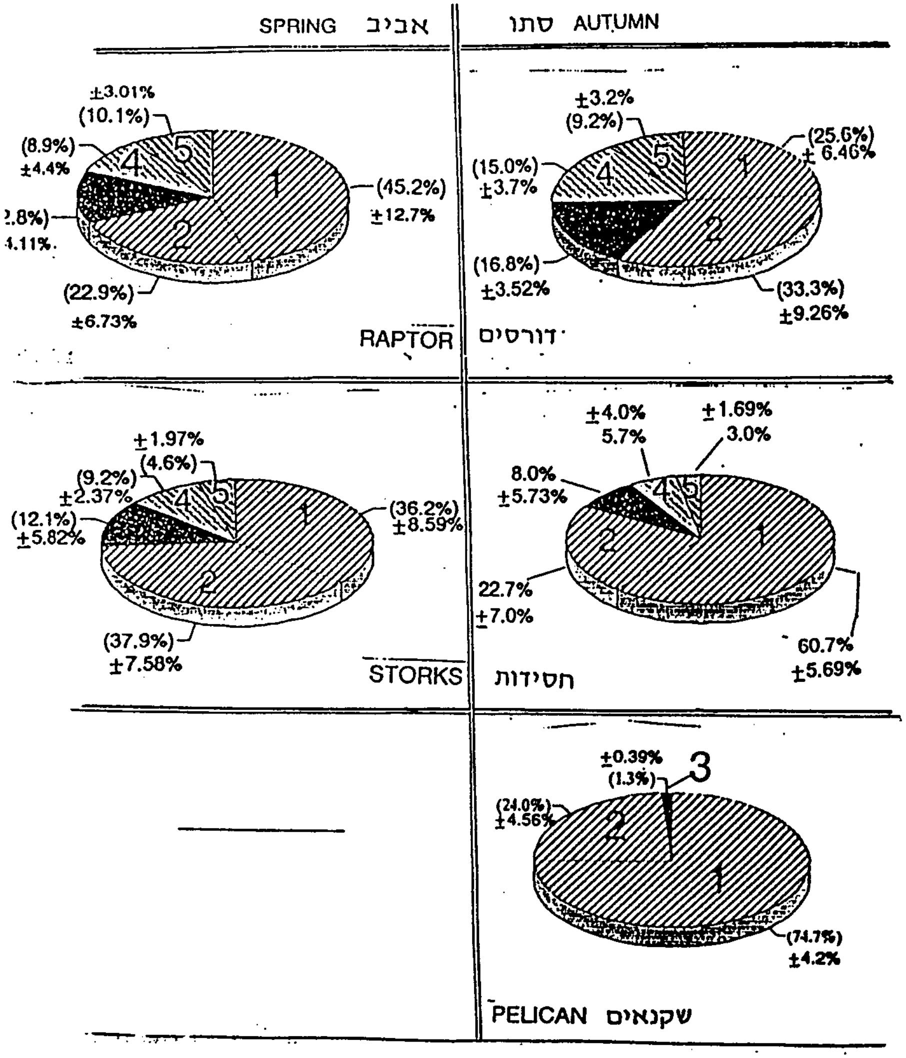
Comparison of the weighted arrival day of different species according to their chronological order of appearance in autumn, shows distinct regularity in the order of arrival according to the type of prey they feed on – from insect eaters to reptiles, fish and finally mammal eaters. **During spring migration the picture is reversed**, and the first to pass are those feeding on endothermic prey and the last the insect eaters. This phenomenon shows the close relation and dependence between migration times and the availability of prey, whose activity varies with changes in weather, with exotherms disappearing first in autumn and returning first in spring.

Fig. 1: Percentage of the total population of each flocking species passing over each day. This figure provides a total picture of flocking species distribution in time in spring and autumn.



Five degrees of magnitude were determined to describe the intensity of daily migration: 1 - 0-1000 birds per day, 2 - 1000-5,000, 3 - 5,000-10,000, 4 - 10,000-20,000 and 5 - 20,000-200,000.

Fig. 2: Mean migration magnitude per day in autumn and spring



Examination of daily raptor migration magnitude during autumn and spring shows (fig. 2), that only in 19% and 24% of the days respectively is there high magnitude migration (10,000–200,000 birds per day), in 12.1% and 16.8% of the days medium magnitude migration (5,000–10,000 birds per day) and in 58.9% and 68.1% of the days migration is sparse (0–5,000 birds per day). Storks show less days with peak magnitude than raptors (13.7% and 13.8%), and pelicans have no days with heavy migration.

The distribution of daily migration magnitude is important biologically to differentiate between the migration patterns of different bird groups (pelicans, storks and raptors). No less important is its significance in the applications of the conclusions of this study by the Israel Air Force. BPZ (Bird Plagued Zone) regulations, which prevent fighter aircraft flying at low altitudes during the migration seasons, have been formulated as a result of this study The migration magnitude distribution shows that low altitude flights are possible during the migration seasons on days when the magnitude is 1, or with a calculated risk, on magnitude 2 days. The data presented shows, that in autumn fighter aircraft can fly at low altitudes 25.4%–58.9% of the time and in spring 42.5%–68.1% of the time. Since soaring bird migration occurs during 6 to 7 months a year, this information is of great operational importance for the IAF.

Migration axis movements on a daily scale

Based on data from the ground observer network, the motorised glider and radar photo sequences from the Ben–Gurion International Airport surveillance radar, it may be seen that the migration axis which passes west of the mountains and parallell to the Mediterranean coast in autumn is deflected at the beginning of the day from east to west for 10–25 kilometers, depending on weather conditions and flock roost locations. Towards 10:00–11:00 the daily breeze blowing from the sea influences the migration axis, which is slowly deflected back to the east. The west–east drift is greater in the data of the Northern Valleys Survey and shorter in the Cross–Samaria Survey due to variations in topography.

In the Eilat Mountains wind flow plays a similar role, but due to the topography of the southern Arava Valley, which causes a change in wind direction, the axis moves during the day in a north–south direction.

Fig. 3: Photo sequence (1-6) - West-east daily fluctuations in Lesser Spotted Eagle (Aquila pomarina) autumn migration as seen on the Ben-Gurion radar (27.9.88).

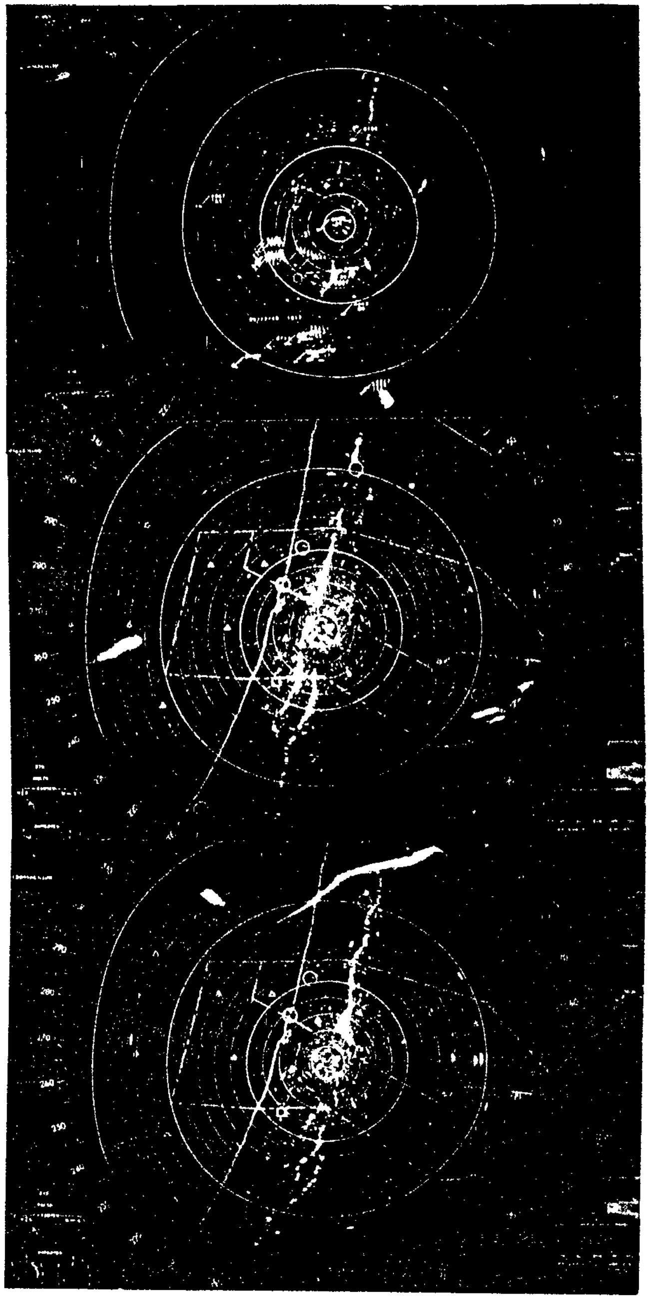


Photo 1: 09:13 - Lesser Spotted Eagles after leaving roost, 14 km east of the coast.

Photo 2: 10:50 - The Lesser Spotted Eagles on a western axis, 8.5 km east of the coast.

Photo 3: 11:35 - The Lesser Spotted Eagles drift 13 km east of the coastline.

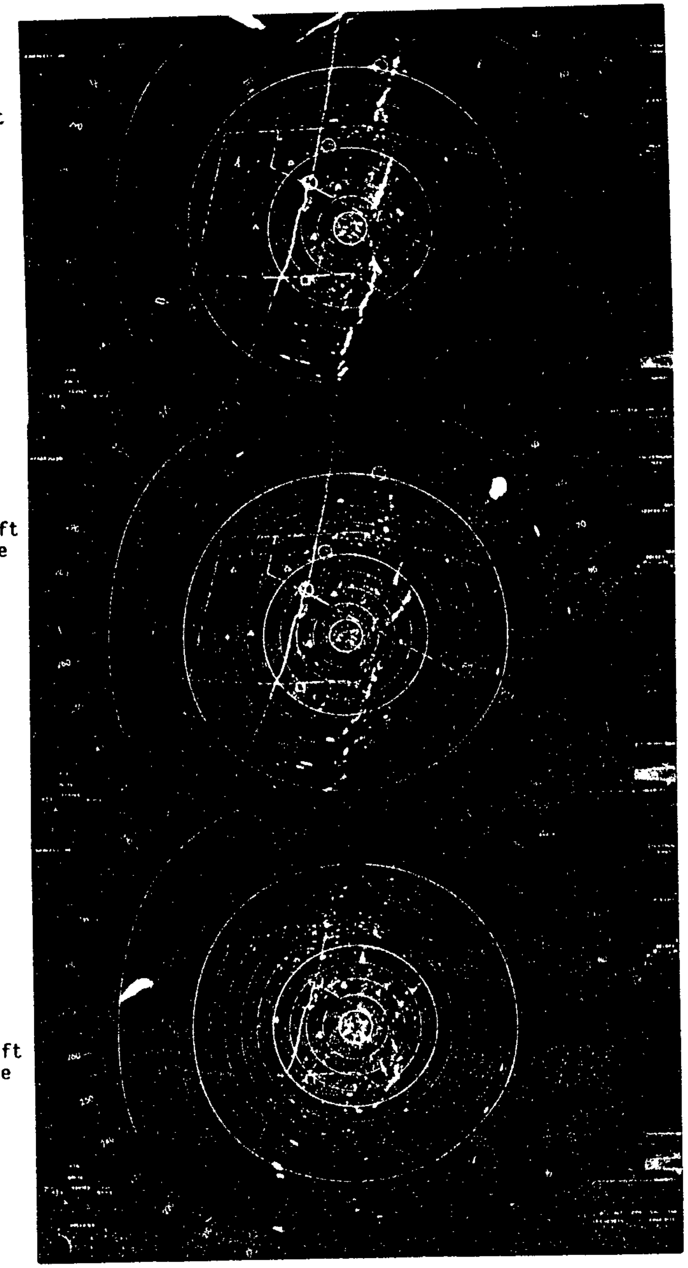


Photo 4: 12:06 - The Lesser Spotted Eagles drift 19.3 km east of the coastline.

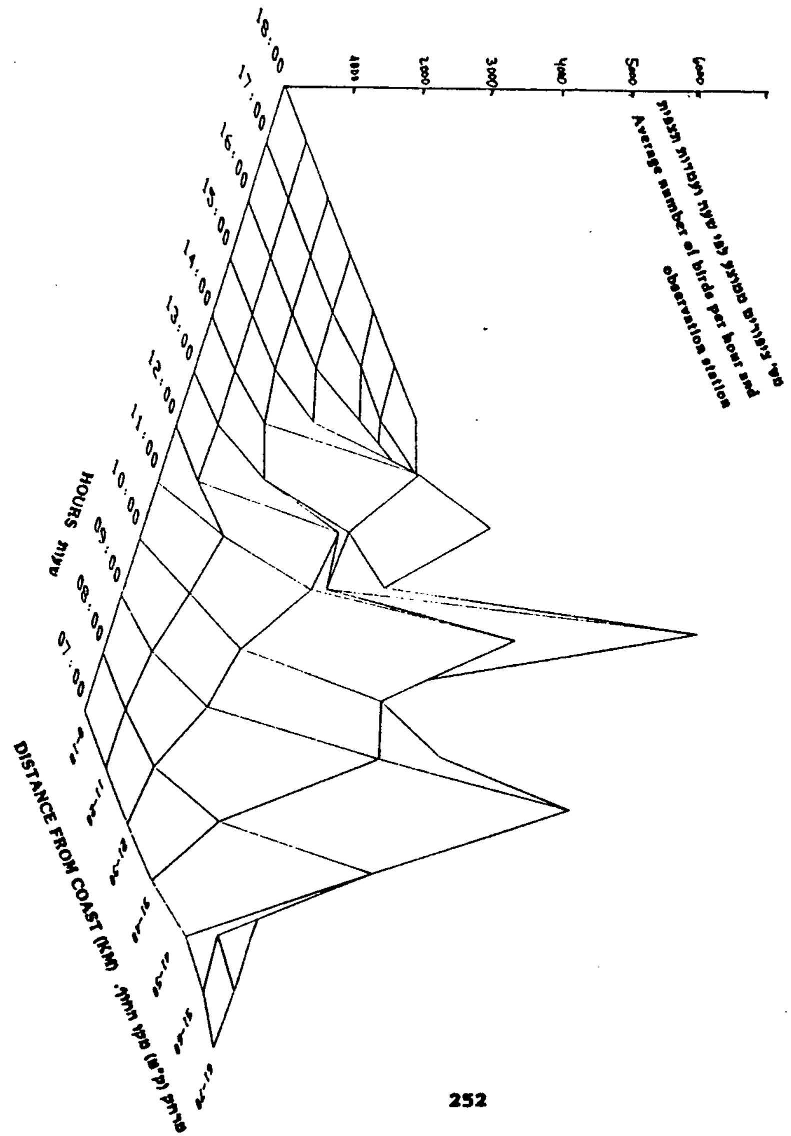
Photo 5: 13:34 - The Lesser Spotted Eagles drift 20.4 km east of the coastline.

Photo 6: 14:13 - The Lesser Spotted Eagles drift 23.3 km east of the coastline.

מהרצף המוצג נראה, כי ציר נדידת עיטי החורף בנדידת הסתיו נסחף במורדות הרי יהודה ושומרון תוך 1:37 שעות 5.5 קילומטרים מערבה, ובהמשך החל להיסחף מזרחה, לטווח של 14.8 קילומטרים, תוך 2:23 שעות.

Fig. 4: Honey Buzzard (Pernis apivorus)"Isobars" along the Northern Valleys axis in autumn.

This is a three-dimensional illustration portraying the daily average of 29 observation days in which a large number of Honey Buzzards passed over during three survey years (1988–1990).
Z-axis – number of birds
Y-axis – distance from the coast
X-axis – hours of the day

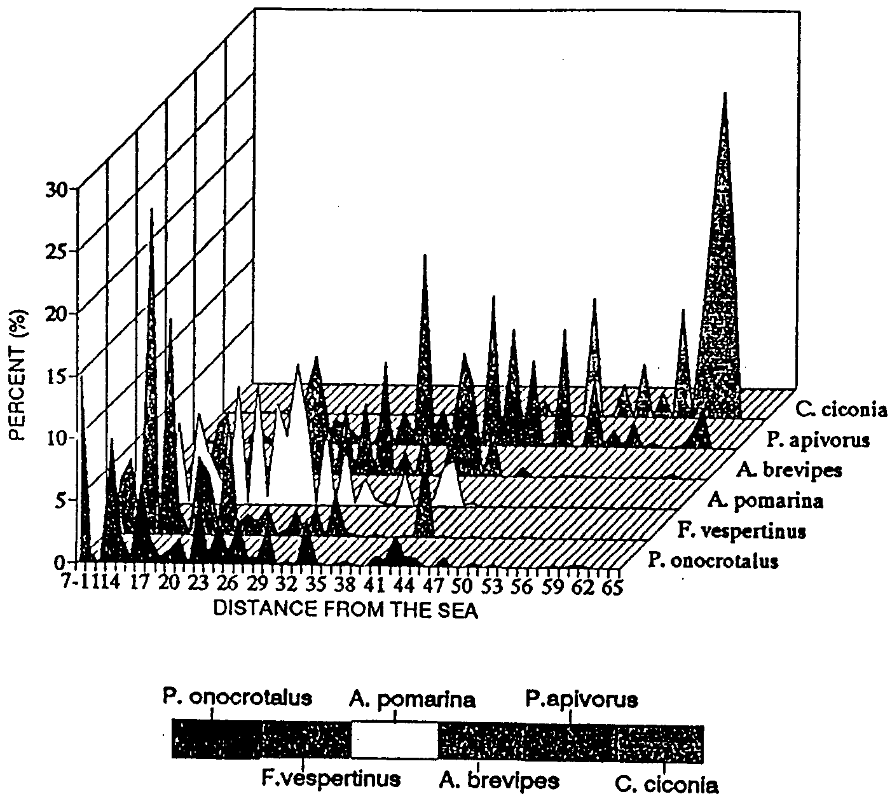


Migration axis movements on a seasonal scale

In the Northern Valleys survey seasonal variations in the horizontal migration axis are very obvious. Between 1987–1990 data on stork and pelican passage was also gathered during the whole autumn migration season. Fig. 5 illustrates the distribution of six flocking species arrival times as a function of distance from the coast. Below, the data for 90% passage and average peak day for each species appears.

The data clearly shows an inverse relation between arrival time of flocking species and average distance from the coast. Storks, the first to appear, migrate along the most easterly axis. As the arrival date becomes later, the axis drifts west towards the coastline. Pelicans, the last to appear, migrate along the most westerly axis. Glider data shows, that pelicans, along the Kfar Kassem – cross–Samaria line, and further south in the Gaza area, concentrate almost completely in the west, at ranges of 5–10 km from the coast.

Fig 5: Seasonal variations in the horizontal migration axis for six species – Northern Valleys autumn migration survey.



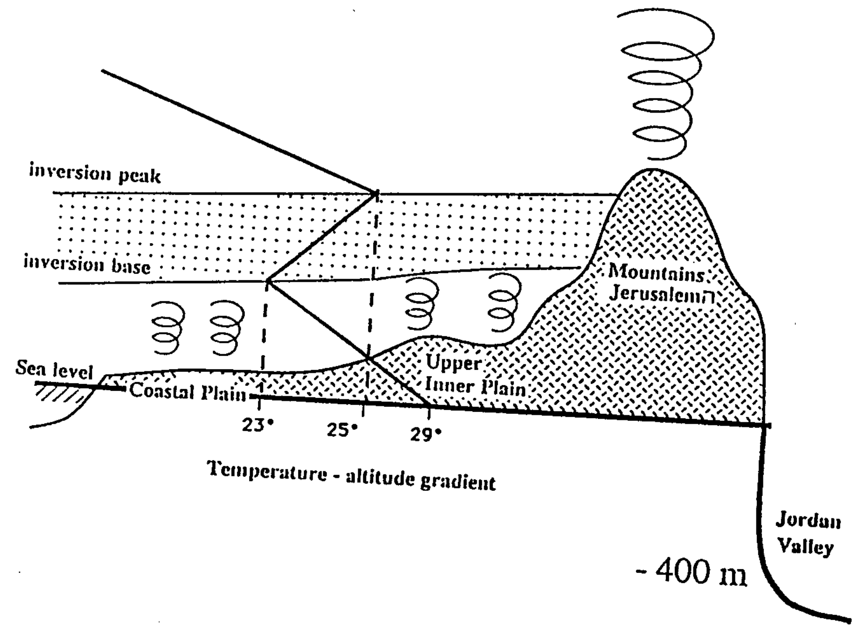
6	5	4	3	2	1	
7/11-18/9	13/10-25/9	5/10-21/9	26/9-14/9	14/9-30/8	12/9-16/8	תאריכי מעבר 90% מהאוכלוסייה (Appearance 90% population)
26/10	3/10	1/10	21/9	7/9	21/8	יום שיא ממוצע (Mean peak day)

Fig. 5 portrays movements of the migration axis during the season, which starts in August in the east (storks) and eventually moves principally to the western part of the country (Lesser Spotted Eagles, Red-footed Falcons and Pelicans). Climate plays a major role in determining seasonal fluctuations:

In summer, the weather is dominated by a sub-tropical high, which prevails along the entire African coast up to our area (a regional barometric high), combining with the Persian trough in its southern part. The hot, dry air which comes from the Persian Gulf, cools off when it reaches the Mediterranean and absorbs moisture. The cool sea air creates and inversion in the temperature-altitude gradient – the marine inversion.

This inversion creates a stable layer, in which the temperature increases with altitude instead of decreasing (1C for each 150 m.). As a result good conditions for thermals develop, and as can be seen in fig. 6, the eastern area is the most appropriate for migration, and therefore all migration in August converges in the east.

Fig. 6: Scheme of the inversion on a west-east section (noon – August) The thick' diagonal line represents the temperature-altitude gradient.



In September the Persian trough gradually recedes, replaced by the Red Sea trough which comes from the south. Temperature differences between sea and land decrease, the inversion influence gradually diminishes, disappearing completely in October. At the same time the migration axis moves from east to west. About half of the stork population which returns north in spring during March and April, when summer weather conditions are still absent, and no inversions exists, migrates accordingly along the western axis over the western slopes of the mountains (unlike in autumn when storks are absent).

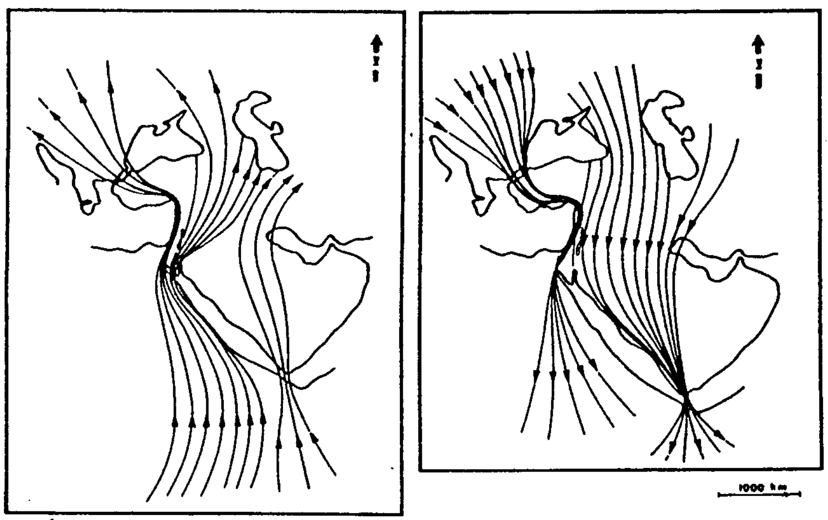
Variations in migration magnitude between spring and autumn on a global scale

There are significant differences in the migration magnitudes of the various soaring bird species over Israel in autumn and spring. For example: only one species, the Steppe Eagle (Aquila nipalensis) flies over the Eilat Mountains in autumn, compared to massive migration of more than 30 species in spring; in autumn White Storks (Ciconia ciconia) pass over only along the Jordan Valley axis, whereas in spring about half the population also passes over the western edge of the central mountain range; Honey Buzzards fly along the Western Route in large numbers in autumn, while concentrating almost totally in the Eilat Mountains in spring, and so forth. The reason for the variation in different species appearance is related to their global migration routes, between breeding and wintering grounds, in relation to the Red Sea which they avoid crossing, thus following different routes in autumn and spring (fig.7). The breeding grounds range of different species in relation to the location of Israel (35 longitude) is an additional factor determining different migration routes over Israel in spring and autumn.

Fig. 7: Migration flow scheme in spring and autumn (Yom Tov' 1988)

A:SPRING ב. נדידת האביב

B, AUTUMN א. נדידת הסתיו



MPLEMENTATION OF THE STUDY RESULTS IN THE ISRAEL AIR FORCE AND CIVILLIAN FLIGHT SYSTEM

a. Study of **variations in daily migration magnitude** made it possible to develop a real-time warning system based on the ground observer network and the radars at Ben-Gurion International Airport. On evenings when light migration was observed, low altitude flights were approved even at the height of the migration season. If, at any time, heavy migration was spotted by the observers or radar, low altitude flights were immediately cancelled, and pilots returned to BPZ regulations in effect during the migration season. This procedure permitted about 35% of low altitude training flights to take place during the height of the season.

b. The **preciseness of migration wave arrival times** allowed prediction of arrival and departure times of flocks in advance, as well as preparation according to organised flight procedures in the IAF and civillian flight.

c. **Migration axis movements** were known in advance as a result of this study, making it possible to open and close flight areas accordingly during the migration seasons. The regularity in daily axis movements permitted real-time warnings to IAF base control towers and other elements.

This is the seventh year BPZ regulations during migration seasons have been in effect. The number of bird-aircraft collisions has been reduced by 81.8% compared to the period before these regulations, and average annual damage has declined by 88%.

The following account proved to be an excellent test case for examining the efficiency of the various systems developed in this study:

a. On 5.9.91 a giant flock of White Storks (47,000) passed over Israel. The flock was located at 10:40 by one of the ground observer teams west of Bet She'an in the Jordan Valley. Between 10:40-10:50 the first mass of 9,000 storks passed over, followed immediately by a second mass of 38,000, between 10:51-11:20.

b. The team co-ordinator (James Smith from England) immediately informed the survey head (Dan Alon) via the portable military radio transmitter, who then called the Bird Center at the Ben-Gurion radar on the car phone.

c. The controller at Ben-Gurion immediately changed to a 60 mile scale, instead of the usual 30, locating the stork mass. He then reported its exact position to the Israel Air Force and continued systematically tracking the flock along the eastern axis (west of the Jordan Valley) up to the central Negev.

d. At the same time the control unit of the IAF located the flock because of its size, and commenced transmitting constant warnings to aircraft, while continuing to follow the flock for 6 hours, until 17:00. The tracking was documented on video, until the flock disappeared in the vicinity of Jabel Ya'alek in central Sinai, where it probably landed to roost.

e. By using the data from this study from which we knew that storks usually take off in the morning at about 8:00, and that their flight velocity in the first two hours is slower than during the rest of the day, we calculated that the storks had covered about 75 kilometers until the moment of discovery. This would agree with a roost in the Hula Valley, which is known to be a preferred spot, the night before. From the moment the flock was located until it disappeared from the IAF radar screen near Jabel Ya'alek, the storks covered a distance of 310 km. This would bring the total distance covered in continuous migration during one day to 385 km.

The continuous tracking with a combination of two radars and ground observers confirms the conclusions of this study and provided reliable real-time warnings to IAF aircraft along most of the country.

ACKNOWLEDGEMENTS

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Special thanks are due to the IAF officers and radar operators who helped make this project a classic example of fruitful cooperation between military and civillian elements.

SELECTED BIBLIOGRAPHY

Cramp, S. et al. 1980. Handbook of the Birds of Europe the Middle East and North Africa, The Birds of the Western Palearctic. Vol. II. Hawks to Bustards. Oxford University Press. Oxford, London, New York.

Christensen, S. et al 1982. The spring migration of raptors in southern Israel and Sinai. Sandgrouse 3: 1–42.

Evans, P.R. and G.W. Lathbury 1973. Raptor migration across the Straits of Gibraltar. Ibis 115: 572–585.

Kerlinger, P. 1989. Flight Strategies of Migrating Hawks. Chicago Press.

Leshem, Y. 1988. Following soaring bird migration from the ground, motorized glider and radar at a junction of three continents. Proceedings of the 19th Meeting Bird Strike Committee of Europe (BSCE): 193–214.

Leshem, Y. 1989. Following the raptor migration from the ground, motorized glider and radar at a junction of three ontinents. Raptors in the Modern World: Proceedings of the 3rd World Conference on Birds of Prey, Eilat 1987: 43–52.

Leshem, Y. 1990. The development of bird migration real-time warning system for the Israeli Air-Force utilizing ground observers, radar, motorized glider and drones, and preliminary report the use of transmitters received by sattelite as a new method. Proceedings of the 20th BSCE Meeting, Helsinki, Finland. W.P. 12:93–102.

Leshem, Y. 1991. Study and forecast of fall and spring migration of soaring birds over Israel and the effect of climate factors on migration. Ph.D. thesis submitted to the Senate of Tel-Aviv University.
Mindell, D.P. 1985. Biogeography of New World migrant raptors: a review. In Proceedings of the Fourth Hawk Migration Conference, M. Harwood (ed.), 369–385. Rochester, NY: Hawk Migration Association of North America.

Pennycuick, C.J., T. Alerstam and B. Larsson, 1979. Soaring migration of the Common Crane Grus grus observed by radar and from an aircraft. Ornis Scand. 10: 241–251.

Yom-Tov, Y. 1988. Bird migration in Israel. In the Zoogeography of Israel. W. Jung Publishers, Dordrecht Beston Manchester: 497–514.

A method of identifying bird species from a blood-stain or shred of tissue.

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Abstract

In many cases the remains of a struck bird are not sufficiently complete to perform a reliable identification based on secondary characteristics. DNA technique of Polymerase Chain Reaction, PCR, are by now applicable for species identification in bird strikes. Only minute amounts of DNA are needed, because this technique is capable of replicating enough identical DNA for base sequencing. Collecting and preparing blood stains and tissue remains can easily be carried out by everybody. Blood and finely partitioned tissue is dropped in a Nunc cryo-tube filled with a buffer solution and can be stored at room temperature or in a refrigerator. Alternatively, materials can be collected in a clean plastic folie and stored in a deep freezer.

A proportionally large number of birds involved in bird strikes fail to be categorized into species. In many of such cases the remains of the struck bird are not sufficiently complete to perform a reliable identification based on secondary characteristics. However, blood and flesh remains being left on aircraft body are in fact a species specific characteristic if the heritage material of the bird is considered. DNA techniques are by now applicable for species identification in bird strikes.

The aim of this paper is to draw attention to the application of the new DNA technique of Polymerase Chain Reaction, PCR, as an ultimative method of identifying bird species when other procedures are inadequate. Further, based on this DNA technique followed by direct sequencing it will in some cases be possible to detect geographical origin of the individual involved. Furthermore, it is possibly to state whether a blood-stain detected on an aircraft really originates from a carcass actually found on/near the runway.

At the Institute of Population Biology, Zoological Museum, Copenhagen, application of PCR technique is at an advanced stage. The information present in this paper derives merely from a personal conversation with Dr. Peter Arctander from this institute and from papers published (e.g. Arctander & Fjeldså 1991, Fjeldså & Arctander 1989).

This PCR based technique differs from other known DNA approaches in analysing the base sequence. Furthermore, only minute amounts of DNA are needed, because this technique is capable of replicating enough identical DNA for base sequencing. The application of PCR technique can now go on routinely and rationally, and is effective. However, as the work is still in a developmental stage PCR analysis implying a high cost accounting to use. The actual price of a total PCR sequencing analysis, from sending in a test sample to receiving an answer, is quoted to be a sum around about 150 USD. This price, however, will be reduced markedly in future.

As yet, a DNA reference collection of comparative sequences is not established for all known or potential species involved in bird strikes. However, test samples from around one thousand of species from all over the world are actually collected and stored at the Zoological Museum in collaboration with the Institute of Population Biology, Copenhagen. This sampling is still going on, but a program for base sequence analysis of the collection stills awaits starting.

On the other hand, collecting and preparing blood stains and tissue remains is very cheap to perform and can easily be carried out by everybody without complicated instructions. Furthermore, storage of test material pose no problems. Thus, henceforth there is no harm in collecting DNA samples for storage in situations where alternative tools for species identification are inapplicable. Hopefully, some day when PCR tests are adequate we have not missed our opportunities if, for instance, bird strike statistics are needed for identification of the species in question.

How are we to sample and store collected material in practice? DNA is a stable molecyle. Under conditions experienced in bird strikes the bird remains on aircraft is mostly dryed by wind and sun or by freezing. In such cases DNA molecyles are often kept intact suitable for analysis. Blood (fresh or dryed) and finely partitioned tissue is dropped in a 4.5 ml. Nunc cryo-tube filled with a buffer solution. Recommended buffer is 25% DMSO (Dimethyl Sulfoxide) with 5M NaCl. This solution prevents oxidizing and enzymatic degradation of DNA. When sampling has finished the tube can be stored at room temperature. For longtime storage it is recommended to use a refrigerator. As the PCR technique is very sensitive to contamination with foreign DNA clean equipment must therefore be used when sampling. Alternatively, without having disposal of buffer filled cryo-tubes, materials can be collected in a clean plastic folie and stored in a deep freezer.

References

Arctander, P. & J. Fjeldså, 1991: DNA studies for avian systematics - techniques, virtues and perspectives of DNA collections.- In: C. Edelstam & M. Mina (eds), 1991. Museum research in vertebrate zoology, Swedish Museum of Natural History, Stockholm.

Fjeldså, J. & P. Arctander, 1989: Perspectives of DNA techniques for game biology.- Finnish Game Res. 46: 4-16.

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BIRD STRIKE PREVENTIVE MEASURES IN THE ISRAELI AIR FORCE

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ABSTRACT

As a result of physical and ecological conditions in Israel there is a large quantity of birds of a large variety of species, that live in, visit, and migrate over Israel. Since air space is quite limited in Israel, birds form a serious hazard for the Israeli Air Force(IAF). Therefore, the IAF designated a team of female soldiers who's work strictly involves bird strike prevention in and around military airfields. Their work involves both bird hazard avoidance and real time dispersal.

BIRD STRIKE PREVENTATIVE MEASURES IN THE ISRAELI AIR FORCE

1. INTRODUCTION

There are several reasons for the large amount of bird strikes in Israel during both high and low altitude flight.

1. Israel's unique position as a corridor between 3 continents: Europe, Asia, and Africa results in the migration of millions of birds every fall and spring over Israel.

2. The Syro-African fault, where temperatures are relatively high and the large differences in topological altitude, create ideal conditions for thermics, and hence the passage of soaring birds.

3. Our rich and diverse natural habitats and a widespread concienceness of nature preservation, create habitats with excellent conditions for an extended stay of more and more migrating birds, as well as a high level of reproduction among local birds.

4. After Sinai was returned to Egypt, air space for training was greatly reduced, increasing the probability of a bird strike.

5. Air force bases form ideological habitats. Birds are not bothered by their enemy, man, and therefore find a comfortable shelter, nesting and roosting sites.

2. Bird Strike Prevention Measures

All year round there are 3-4 million birds in Israel and their numbers on airfields may reach the thousands. As a result, the IAF designated a team of female soldiers whose job it is to reduce bird strike hazards in Air Force bases. In addition, the IAF is also working with the Society for the Protection of Nature on avoiding bird strike hazards in the air during migration.

Our work on, and a radius of 5km around each airfield is divided into 2 categories:

1. bird hazard prevention
2. real time dispersal

2.1 Bird Hazard Prevention

For bird hazard prevention the team must reduce or eliminate the development of ecological conditions which attract birds to the airfield.

Several factors in the environment are treated:

1) **Agriculture** - in several of the bases there are agricultural fields taken care of by a farmer according to a contract made with the defense ministry/ The IAF receives the farmer's annual plan and approves the types of growths, and cultivation procedures. The team of soldiers, in parallel, inspects the work done by the farmer.

2) **Wild vegetation** - In undeveloped fields there is often a problem with wild flora. The IAF has a budget set aside for the extermination of flora in "sensitive" areas and follows the efficiency of elimination (chemical or organic) as well as interactions between plants and birds, in and passing the base.

3) **Waste dumps** - the soldiers constantly check that the dumps on base are free of organic waste.

4) **Oxidation pools and drainage canals** - these habitats are rich in vegetation, insects and birds: Organic content is high. IAF takes care of proper drainage and plant extermination when necessary.

5) **Trapping during breeding** - entails the finding of active nests and moving eggs and chicks to zoological gardens.

2.2 Real Time Dispersal

Bird strike prevention also entails the dispersal of birds from the airfield. Dispersal occurs on several levels. Firstly, there is real time dispersal working on the different birds' senses. Acoustic communication between birds is the most highly developed form of communication. Therefore, different vocal techniques are used.
1.artificial techniques include: gas tanks, scare cartridges, sirens.
2. bioacoustic - taped distress or alarm calls of different birds are used.
Visual techniques:
1. artificial - brightly colored models of birds of prey, and mimicry of their eyes to disperse small birds.
2. natural - hanging o f bird carcasses in problematic areas.\Finally, working on their sense of touch, there are different types of glues and sprays which cause bird claws to stick, these are used in buildings and closed places.

Another level of action is population reduction by trapping and hunting.

3. Problematic bird species in Israel

There are several bird species in Israel which are problematic, and pose a hazard to flight.

- During migration there are paths at different heights where pelicans, storks and raptors fly. Pelicans and storks stop for a rest in attractive areas and sometimes stay in Israel for the winter and even to nest.
- Israel has a rich variety of Charidiiformes some of those found on airfields are the spur-winged plover as well as lapwings.
- Several types of ducks stay for the winter such as: mallards, gargeneys, and teals.
- Gulls as well as meadow larks (Haplopterus spinosus), spend the winter in Israel and pose a serious problem in airfields.
- During the different seasons there are also various species of passerines which are problematic.
- In addition, there are desert strips which attract sandgrouses (Pterocles coronatus), and houbara (Chlamydotis undulata).
- Stable birds include: the stone curlew (Burhinus oedicnemus), and chukars (alectoris chukar), which are hazardous both when they flock as well as when they are territorial during nesting. Hooded crows (Corvus corone) appear in large numbers on the bases and are extremely hazardous.
- Pigeons in Israel are considered pests and a sanitary problem.

4. Summary

The bird strike crew work according to instructions given to them by their officer in the air force as well as advice given to them by the nature preserve authority. Every problem is dealt with according to the ecological causes and bird behavior.
Our methods of work are first precautionary and then dispersive using different resources together at alternating frequencies to avoid letting the birds habituate to our procedures.

Lately we are working on new projects such as: identification of feather remains after bird strikes, and dog training in order to disperse birds as well as find nesting sites.

Statistically, most of the bird strikes occur at speeds of 50-300 knots and at low level-flying. Most of the strikes are with fighter aircraft. Helicopters and transport aircraft have approximately the same amount of incidents, most of which occur during the morning (until 11:00). It should be noted that most of the bird strikes occur in the air, and not within the airfield range.

In 1947, at 400 feet and 420 knots, a fighter aircraft entered a flock of pelicans - one hit the canopy and apparently hurt the pilot. The plane seemed to drop the left wing, dove with the nose down and crashed.
The last plane which was abandoned and crashed was in 1988 - the pilot ejected safely.

The IAF and the bird strike avoidance crew are constantly investing a great deal of effort to avoid additional bird strikes with planes in both the air and the airfields.
Results show that our efforts are fruitfull.

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RADAR STUDIES ON BIRD MIGRATION IN THE SOUTH OF ISRAEL

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ABSTRACT

Radar information on the directions and the temporal and spatial distribution of bird migration was requested for an expertise concerning the building of a large antenna system for Voice of America in the Arava Valley. Besides the primary task, the project may provide information for bird strike prevention in the Israeli Air Force and offers unique research possibilites on bird migration in a desert environment. The paper comprises the first description of the digital recording methods used in connection with the tracking radar "Superfledermaus". Qualitative data consist of flight paths and wing-beat patterns of tracked birds. Recording of quantitative data is based on conical scanning at different elevations. It provides information on the spatial distribution of birds in a half-sphere of 5 km radius around the radar. A few examples of results are presented and discussed. The quantitative results of the radar observations will also be used for a comparison with different, more traditional observation methods, such as moon-watching, infra-red, and ceilometer observations.

RADAR STUDIES ON BIRD MIGRATION IN THE SOUTH OF ISRAEL

Bruno Bruderer, Swiss Ornithological Institute

1. Introduction

1.1. Background

Plans to build a large antenna system for Voice of America and Radio Free Europe in the Arava Valley have been in discussion since 1986. Considering the fact that the eastern edge of the Mediterranean is one of the world's most important migratory routes for birds, different organizations for nature protection opponed against the construction of this network of wires, which would reach heights between 50 and 155 m and stretch over a distance of about 1,8 km across the valley (1 additional km in the longitudinal axis of the valley is not so important in relation to bird migration). The main question was, how many birds would fly through the area of the principal antenna body and would physically be endangered by a collision with a wire. In July 1991 the Supreme Court of Israel decided that the building of the relay station should be delayed until pertinent research on the potential hazard of the antenna system for bird migration was done. Based on this decision the Swiss Ornithological Institute was asked to do a radar study on the quantities and the flight behaviour of birds migrating through the area in question. The project was named NAMIP (Negev Arava Migration Project) by the Swiss Bird Radar Team.

Besides the scientific significance of the project, the results may be of interest for bird strike prevention in the Israeli Air Force. Great success was attained up to now in preventing strikes during daytime with large flocks of soaring birds by direct warning. There were, however, no radar data available which could show the over all seasonal and diurnal variation of numbers and height distributions of migrating birds in this country. The present paper provides basic information on the aims and the methods of the current radar project.

1.2. The primary tasks

1) To provide quantitative information on the spatial distribution of nocturnal migrants and the distribution of (often flocked) bird echoes during daytime in the area of the planned antenna system and at a comparison site on the plateau of the Negev.

2) To provide information on the flight behaviour (mainly directions) of representative samples of migrants in relation to meteorological conditions, as well as a rough survey of the bird types involved.

1.3. Secondary aims

The unique possibility to do radar studies in a desert environment and the practical significance of the results induced additional aims for the project:

a) Seasonal fluctuations in the volume and composition of migration shall be compared with weather development and with phenological data collected simultaneously by Ben-Gurion University or with published data on seasonal changes in numbers and species composition of migrating birds.

b) The height distribution and the directions of migration shall be compared to the conditions in the lower atmosphere and will help to explain how the birds cope with constraints imposed by environment, such as wind, humidity, oxygen pressure and temperature, and by their own physiological needs. This may impose a trade-off between saving water or energy and accomplishing the journey in due time.

c) Methodological comparisons. The possibility to build optimal radar sites in a flat area, the need for the highest possible back-up for the obtained data, the scientific challenge to calibrate different methods, and the additional interest of the Israeli Army in the future use of own equipment for bird strike prevention is a compelling set of requests for a thorough comparison of different methods. We aim at comparing the information obtained by the NAMIP system with the following other systems: small vertical beam radar, different types of surveillance radars, moonwatching, light-beam, passive infrared.

2. Methods

2.1. Study area and radar sites

The study area (Fig.1) comprises two sites. The primary site is in the Arava Valley, in the vicinity of the moshavs Hazeva and Iddan, about 150 m below sea level. It is operated during the whole time of the survey; the methodological studies are mainly done at this station. The secondary site is on the plateau of the Negev near Sede Boqer, 470 m above sea level. It covers only part of autumn migration and four weeks of optimal spring migration. Its task is to provide a representative sample of data for a comparison between migration on the plateau of the Negev and in the Arava Valley.

Each radar is surrounded by a dam of 40 m radius and 2,5 m height in order to protect the radar as much as possible against echoes of the surroundings. In the flat area of the Arava Valley nearly all the clutter echoes could be excluded by this preventive measure.

2.2. The radar equipment

The basic properties of the tracking radar "Superfledermaus" in comparison with surveillance radars have been described by Bruderer (1971). Additional information on target recognition was provided by Bruderer (1969) and Bruderer & Joss (1969). Automatic tracking and first steps in digitizing flight path data and echo signatures are shown by Bloch et al. (1981). For some recent applications see Bruderer & Jenni (1990) or Bruderer & Liechti (1990). The actual recording system is presented here for the first time. It is based on digital recording of flight paths, echo signatures and spatial distribution of echos (Fig.2). Colour photos showing examples of flight paths are presented in Bruderer & Jenni (1988). Flight paths and echo signatures are referred to as "qualitative" data, the number of echoes per unit volume or time corresponds to the term "quantitative" data.

2.3. The quantitative methods

A half-sphere of 5 km radius above the radar is surveyed every odd hour from 19 hrs to 09 hrs (sometimes from 17 to 11 hrs). The pencil beam of the tracking radar "Superfledermaus" is successively positioned at 9 different elevations (Fig.3). At each elevation the beam scannes the surface of a cone during 18 seconds by rotating once from N- to N-position. Each cell of 30 m length along the 2,2° pencil-beam provides information on the amplitude of all detected echoes. This information is recorded in steps of 0,2°. This record of 411 kbytes per elevation is reduced by a factor of 11 by averaging 11 azimutal scans. The recorded information can be reproduced as a digital colour picture of the radar PPI on the computer screen (see Bruderer & Jenni 1988).

Data processing comprises the following steps: 1) the creation of a clutter mask by superimposing the digital video pictures of the whole season (cells occupied in more than 80% of the cases); these are excluded from further analysis; 2) interactive exclusion of variable clutter (e.g. weather); 3) automatic detection of echo peaks; 4) automatic counting of echo peaks; 5) reducing echoes closer than 3 km by digital STC (sensitivity time control = distance dependent reduction of echo strength) according to the r^4 law; 6) compensation for different detectability of birds at different aspects and with increasing distance beyond 3 km; 7) compensation for increasing detection probability with increasing elevation (more hits per target). The outcome of the procedure are densities (birds unit volume) for selected heightbands (in the present examples height intervals of 200 m, see Fig. 6). and selected periods.

2.4. The qualitative methods

The qualitative methods are based on the capability of the "Superfledermaus" radar to track selected targets. The flight path data of automatically tracked targets are recorded every second. These flight paths are visualized on the computer screen and by an XY-plotter. The data of 20 seconds are approximated by re-

gression lines. Averaging these regression data provides mean values for track direction and ground speed. The bird's heading and air speed is calculated by subtracting the wind vector (measured by tracking pilot balloons) at the corresponding flight level from the vector of the bird's track. For easy comparison the circular distributions of tracks and headings are always presented together (tracks with a heavy line, headings with a fine line). Distributions are presented in the form of polygones, showing the percentage directional distribution in classes of 5°.

The wing-beats of birds tracked by the radar produce a fluctuation of the echo. The "echosignature" corresponds to the wing-beat pattern of the bird (Bruderer 1969) as long as only one bird is tracked (which is usually the case in nocturnal migration). Waterbirds and waders are known for their rather continuous wing-beats, while passerines (songbirds) show typical sequences of beating and pausing phases in horizontal flight. Small birds have high wing-beat frequencies, while large birds flap their wings slowly. These basic features are used for a rough classification of wing-beat pattern during the field work at the radar (Bloch et al. 1981).

Four main wing-beat classes and a class of unidentified targets are used in the present paper for nocturnal migration:

BW	=	big waders and waterfowl	SW	=	small waders and waterfowl
BP	=	big passerines	SP	=	small passerines
U	=	unidentified targets			

3. Results

It is not the aim of the present publication to enter into detailled results. The following graphs should rather provide an idea of the presentation of data and possibilities of future evaluations.

3.1. Basic directions at two sites in the Negev

The basic direction (Bruderer & Liechti 1990) is the mean direction of tracks at a certain site when wind-drift is negligible. It may shift throughout the season, if the directions of the recruiting areas and/or destinations of the involved bird populations change. It is an important reference when different sites or different wind situations at the same site are compared. Due to the low wind speeds observed, the basic directions for the two sites could be based on birds flying in winds of less than 2 m/s. .

The basic direction of autumn migration above the Arava Valley was well concentrated around 192° in nocturnal migration and had three main modes centered around 195° in tracks and headings of diurnal migration (Fig.4). This direction roughly corresponds to the course of the Arava Valley (Fig.1). The basic direction at Sede Boqer was about 202° during nocturnal migration (Fig.4). In diurnal migration the scatter was very wide; it included many local birds (e.g. vultures, falcons, ravens, sandgrouse, and pigeons); for the definition of the basic direction we included only the birds between 115° and 295° (± 90° of the assumed basic direction). The directions of 202° and 208° indicate a slight spreading of the migratory stream towards SW on the plateau of the Negev, comparable to the westward shifting of the mountain ridges and the coastal plain.

3.2. Density of migration

Fig.5. shows the mean altitudinal distribution of nocturnal migrants in the Arava Valley and at Sede Boqer during the period of 21 to 30 September 1991 for five measuring times. The bar diagrams show that highest densities of early autumn migration at Sede Boqer occured in a height band of 200 to 600 m AGL, while in the Arava Valley highest densities occured around 1000 m AGL (i.e. in a height band of 600 to 1600 m AGL). Correspondingly the 50% limit in the Arava is about 600 m higher than at Sede Boqer. 600 m roughly corresponds to the difference in altitude above sea level between the two sites. Densities of migration at Sede Boqer roughly doubled those at Arava in the last decade of September, while in October they were nearly equal (for explanation see discussion). Peak migration occured slightly earlier during night at Sede Boqer than at Hazeva, indicating that large areas with suitable resting areas might be closer at the Negev site. In the course of the season (from mid September to the end of October) the density of migration dropped by a factor of 5, height distribution became more scattered.

3.3. Different wing-beat classes

Fig. 6. shows that the proportions of the different classes of nocturnal migrants changed with the progress of the season. A parallel decrease of the proportion of waders/waterfowl (BW/SW) combined with a relative increase of passerines (BP/SP) was obvious at both sites. During daytime a comparable shift from large soaring birds to flocks of passerines took place during October (Bruderer unpubl.). Compared to central Europe (Bruderer 1971) the proportion of wader/waterfowl echoes is much higher in Israel.

4. Discussion and conclusions

The basic directions at the two sites confirm what was already indicated by surveillance radar pictures (Alfiya 1990): i.e. that the directions of nocturnal broad-front migration slightly spread over the South of Israel, joining on the one hand the course of the Arava Valley and shifting slightly more W on the plateau of the Negev according to the general pattern of the landscape. Due to relatively low wind speeds and fairly stable trade wind conditions, the directions under all wind conditions showed no important difference to the basic directions, except slightly increased drift by westerly winds at Sede Boqer (Bruderer unpubl.). More detailled studies on the directional behaviour of different types of migrants at different flight levels and under different wind conditions are in preparation.

The densities of autumn migration were not basically different at the two sites. Higher densities in the last decade of September may be explained by moderate northwesterly winds prevailing at Sede Boqer, while at Arava winds were weaker and rather from E. Moderate northwesterly winds induce partial drift; compensation may be improved along the mountain ridges at the eastern edge of the Negev plateau and may lead to some concentration of migration at Sede Boqer and to a "lee shade" in the Arava Valley. For pilots it may be of interest that in this country, which is crossed by the most important flyway of palearctic birds migrating to Africa, densities of nocturnal migration in peak season at the levels with most intense migration may reach figures in the order of 1000 birds per km^3, this is about 1 small nocturnal migrant per cube of 100 m side length. It may thus be important to know when and at what flight levels such extreme densities are reached. Mean densities are much lower. Nevertheless, it becomes clear that not only diurnal soaring birds are funnelled through the area of Israel, but also nocturnal migrants occur in higher densities than elsewhere. Calculating migration traffic rates and extrapolating them to the whole width of the area between the Mediterranean coast and the Jordan mountains indicates that about one milliard of birds may cross the area in an autumn season.

The comparison of the flight levels at the two sites showes that the birds flew rather at the same level above sea than above ground. A first hypothesis to explain this observation might be that the decisive elements in the structure of the atmosphere have a similar height distribution over large areas irrespective of topography. Especially the windshear between the trade winds in the lowest parts of the atmosphere and the anti-trades was much lower above ground at Sede Boqer, impeding migration above 500 to 1500 m mainly in the first part of the season. A second hypothesis is, that the birds are avoiding flights in the lowest parts of the atmosphere mainly due to high temperatures, which are extreme in the Arava during early autumn. The second hypothesis is supported by the fact that the difference decreased later in autumn, when the temperatures were lower. These questions are most important for future research and may help to predict the flight levels at which most nocturnal migration must be expected according to the actual meteorological conditions.

5. Acknowledgments

The joint Israeli/American management of the radio relais station rised the funds and assigned the radar project to the Swiss Ornithological Institute, the logistic support to the enterprise TMS. The members of the SBR-Team (T.Steuri, F.Liechti, D.Peter, M.Kestenholz, H.Stark, and C.Bruderer) dropped their own work and got the unexpected project going within one month. I want to thank them for good team-work, for fruitful discussions, for corrections to this text, and for all their efforts in favour of the success of the NAMIP. The whole team is grateful for good cooperation with the meteorological enterprise NIMBUS, with the Israeli collaborators at the two radar sites, and with Ben-Gurion University.

6. References

Alfiya, H. (1990): Nocturnal Migration of Birds over Israel - Changes in Direction and Rate of Migration according to the Time of Night. Bird Strike Committee Europe, WP 20; Helsinki.

Bloch, R., Bruderer, B. & Steiner, P. (1981): Flugverhalten nächtlich ziehender Vögel - Radardaten über den Zug verschiedener Vogeltypen auf einem Alpenpass. Vogelwarte 31: 119-149.

Bruderer, B. (1969): Zur Registrierung und Interpretation von Echosignaturen an einem 3-cm-Zielverfolgungsradar. Orn.Beob. 66: 70-88.

Bruderer, B. & L.Jenni (1988): Vogelzug. Bericht zu Handen der Freunde der Vogelwarte. Sempach.

Bruderer, B. & L.Jenni (1990): Migration Across the Alps. In: Bird Migration. Physiology and Ecophysiology (Ed. E. Gwinner), pp. 60-77.

Bruderer, B. J.Joss (1969): Methoden und Probleme der Bestimmung von Radarquerschnitten frei fliegender Vögel. Rev. Suisse Zool. 76: 1106-1118.

Bruderer, B. & Liechti, F. (1990): Richtungsverhalten nachtziehender Vögel in Süddeutschland und der Schweiz unter besonderer Berücksichtigung des Windeinflusses. Orn. Beob. 87: 271-293.

Captions to figures

Fig.1. The location of the two radar sites in southern Israel. For better orientation the main towns in the area are indicated: T = Tel Aviv, J = Jerusalem, BS = Be'er Sheva, SB = Sede Boqer, EA = El Arish, EL = Elat, AQ = Aqaba. Note the direction of the Arava Valley (about 190°) between the Dead Sea and the Gulf of Elat and the direction of other topographical elements (such as the Mediterranean coast, the coastal plain, and the mountain ridges of the Negev) which shift away from the Arava to the South. The main radar station is in the Arava Valley, the secondary station in the Negev near Sede Boqer (both indicated by black dots)

Fig.2. The tracking radar "Superfledermaus" and its connections to the recording and peripheral equipment (PPI-display on computer monitor, display of flight paths on computer monitor, XY-plotter for flight paths, Xt-plotter for wing-beat signatures).

Fig.3. Elevation angles at which the pencil beam of the radar scans the sky in order to provide information on the spatial distribution of birds in a half-sphere of 5 km radius. The elevations are given in milles instead of degrees; 1600 ‰ correspond to 90°, 1° corresponds to about 17,8 ‰.

Fig.4. Distribution of the main wing-beat classes of nocturnal migration for three periods in the autumn of 1991 over the Arava Valley and the area of Sede Boqer. The wing-beat classes are: BW = big waders/waterbirds, SW = small waders/waterbirds, BP = big passerines, SP = small passerines, U = unknown birds.

Fig.5. Distributions of tracks and headings under calm wind conditions (windspeed <= 2 m/s). Each graph provides the number of birds (N), the mean direction of tracks (track) and of headings (head). The polygones are percentage distributions per 5° classes.

Fig.6. Average altitudinal distribution in the decade of 21 to 30 September per measuring time throughout night (19, 21, 23, 01, 03 hrs) for Arava (a) and Sede Boqer (b). The altitude of the 50%- and 90%-limit of migration is indicated by filled and open arrows, respectively.

FIGURE 1

Location of the two radar sites in southern Israel

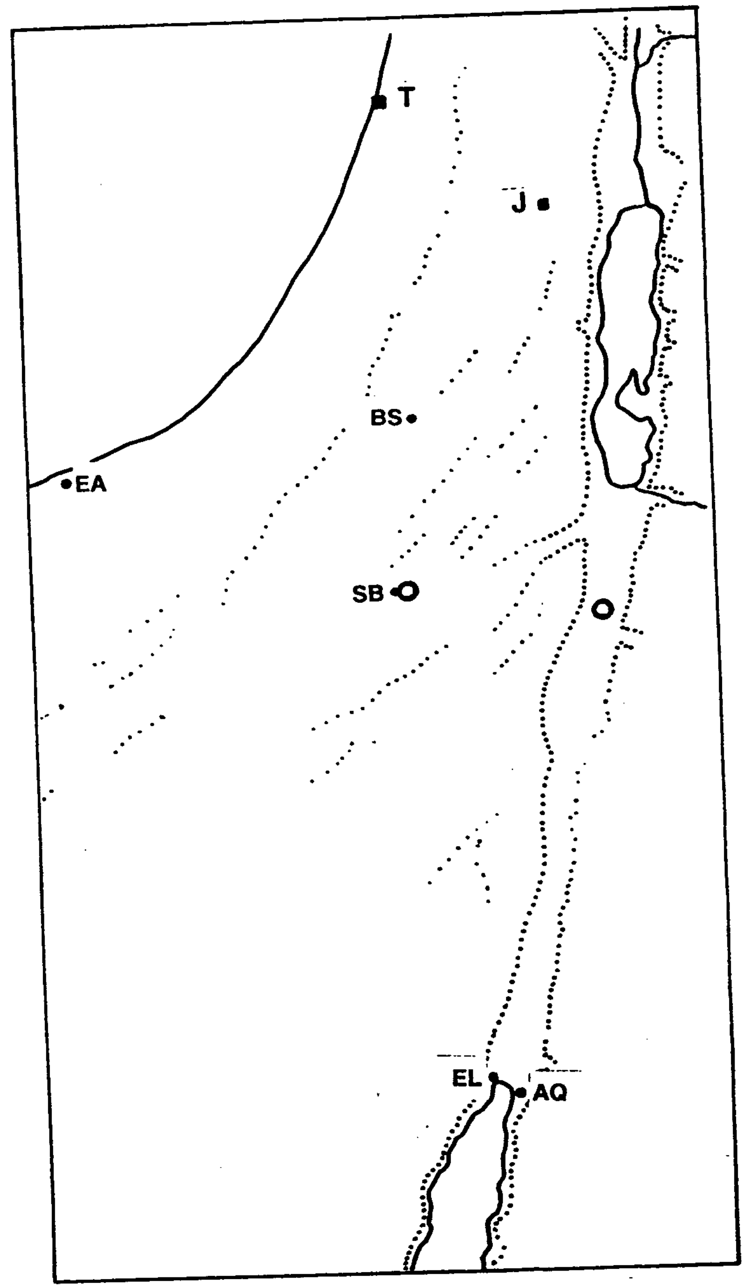


FIGURE 2

Tracking radar "Superfledermaus" and recording equipment

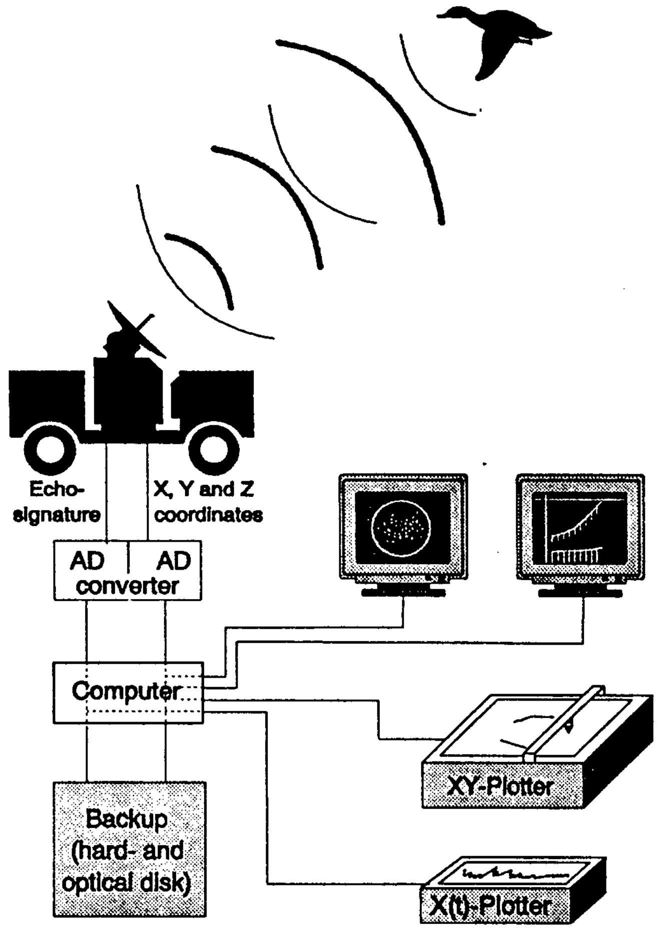


FIGURE 3

Elevations of the radar beam for conical scanning

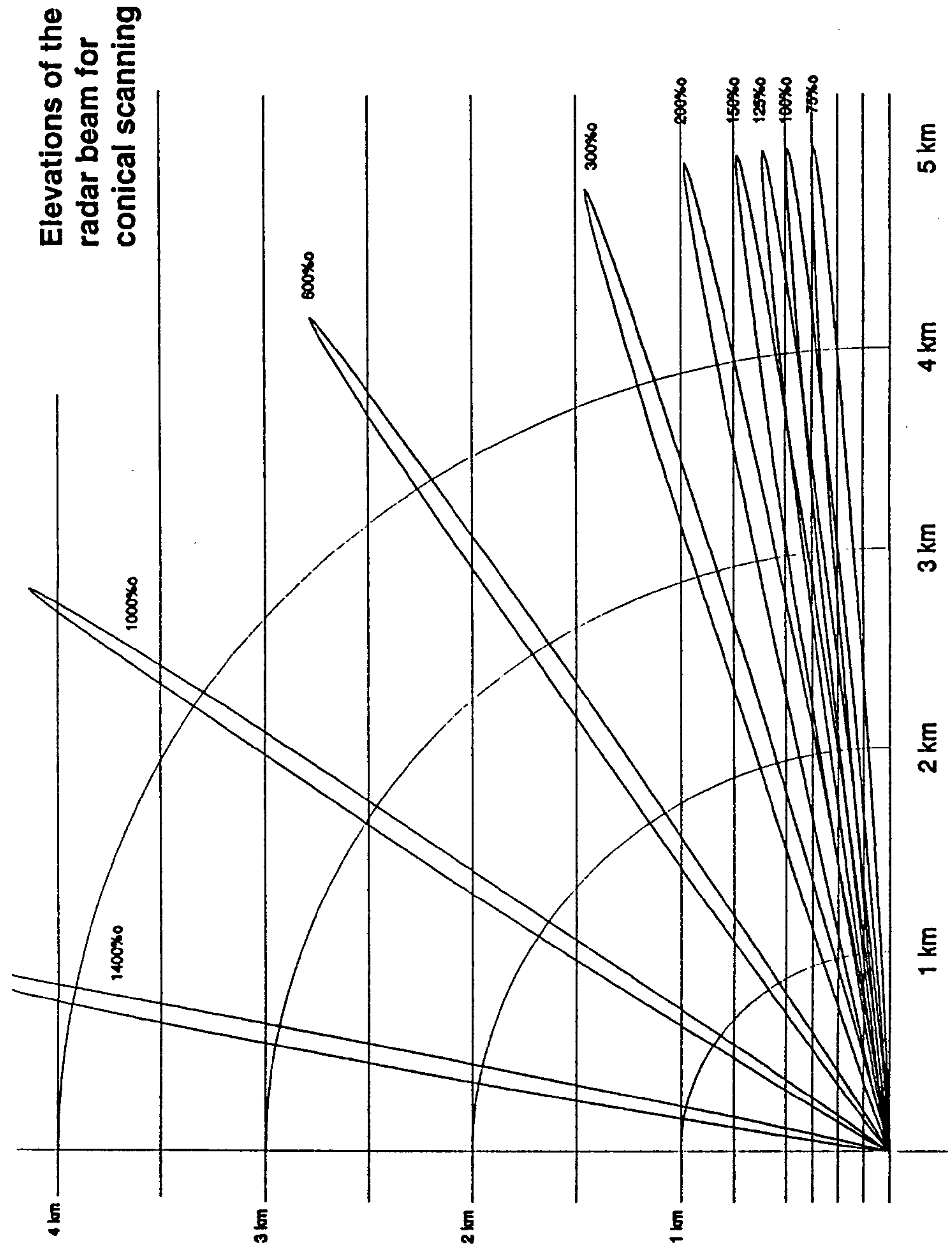


FIGURE 4

Proportions of wing-beat classes of nocturnal migration for three autumn periods

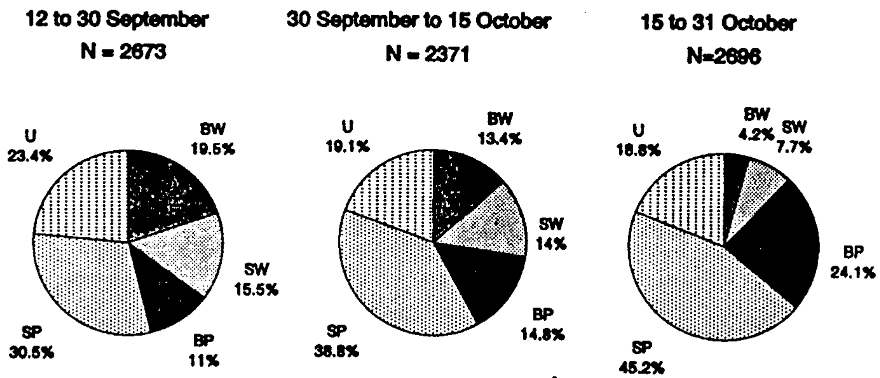


FIGURE 5

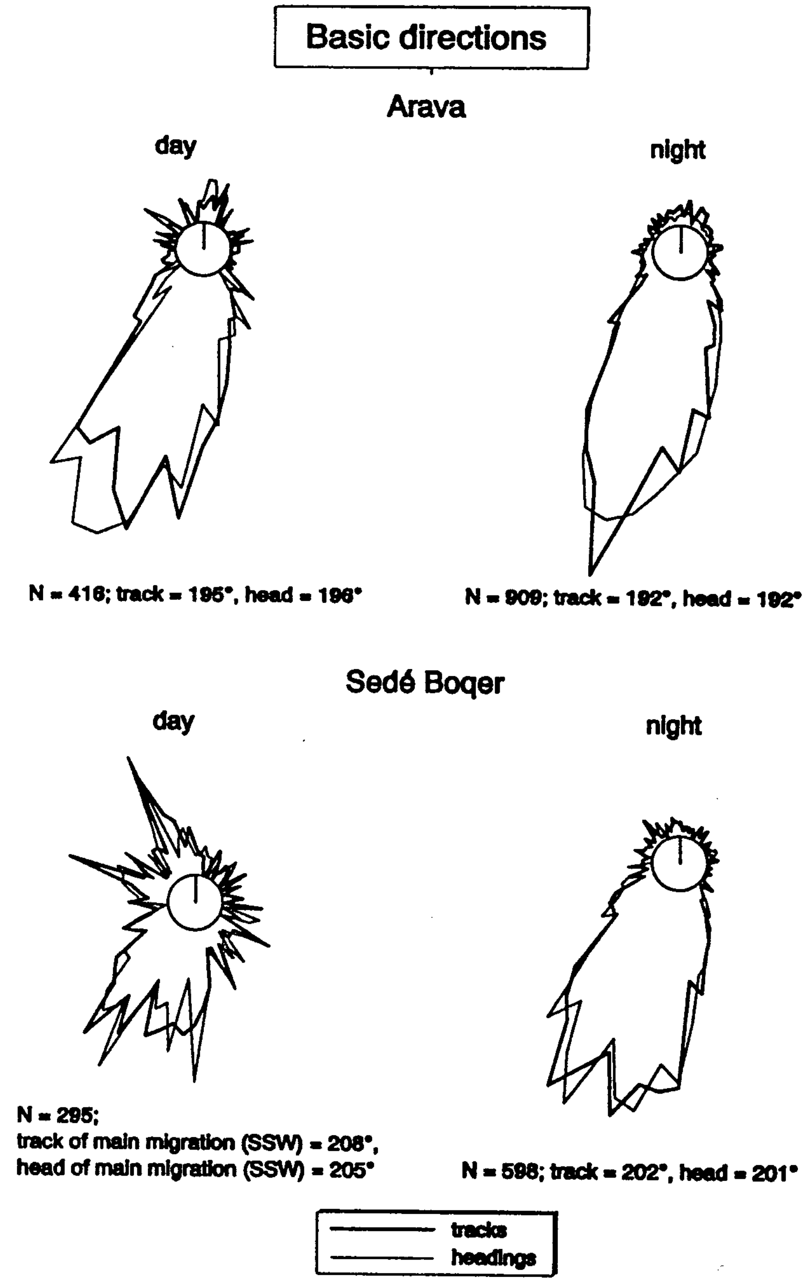
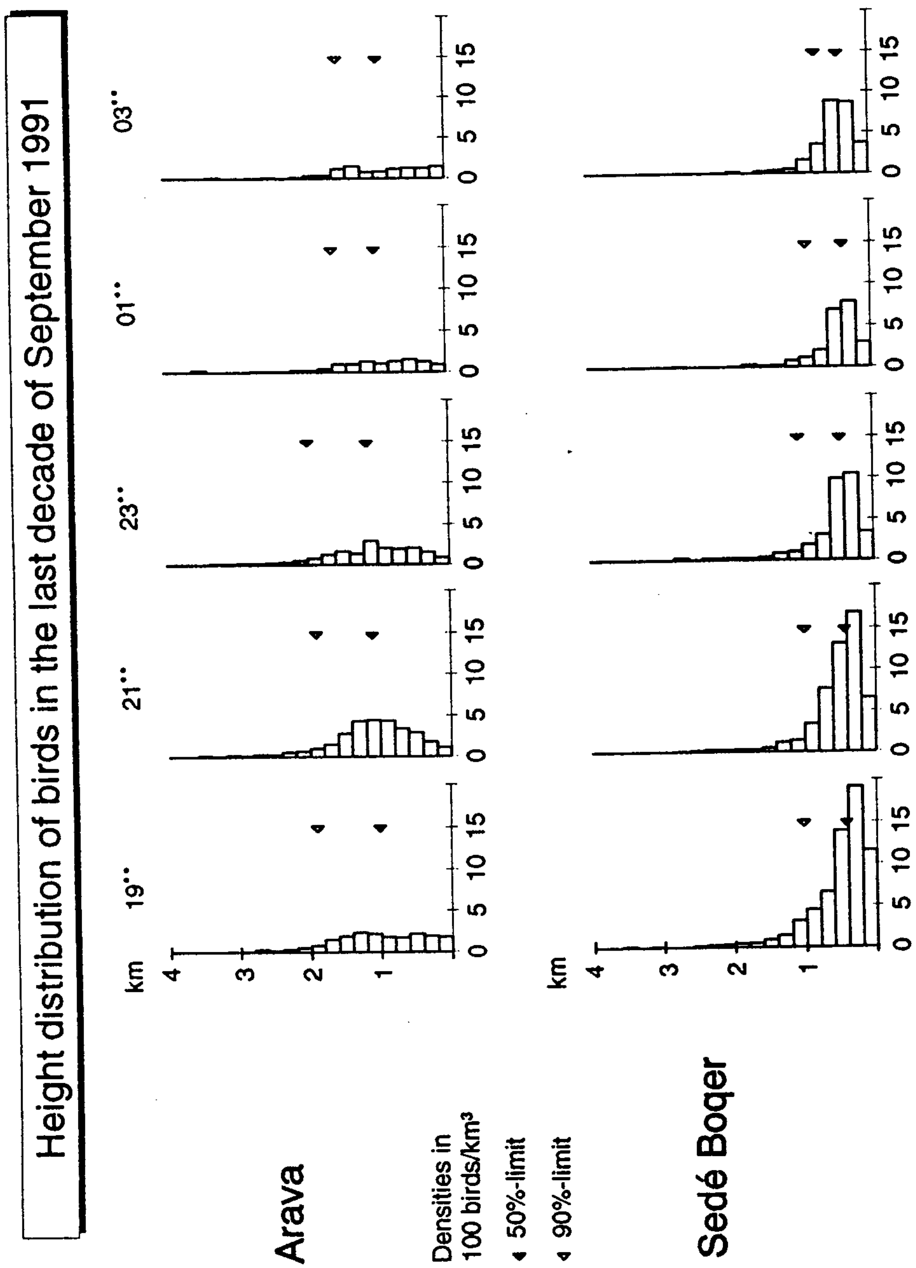


FIGURE 6



BSCE 21 / WP 29

Jerusalem,
23-27 March 1992

BIRD STRIKES ANALYSIS IN ESTONIA 1989-1991

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ABSTRACT

This working paper is continuation of WP20 at BSCE 20. During period 01.01.1989-17.07.1991 55 bird strikes were registered with Estonian aircraft in 13 airports and its vicinity in European part of the former USSR. There were no deaths, injuries or aircraft losses but 5 engines were damaged. Total loss has formed about 300 000 roubles in old prices.

Introduction

This report covers bird strikes, which occurred since 01.01.1989 till 17.07.1991, when position of aviational ornithologist was closed due to difficult economical situation in Estonian Civil Aviation Department (ECAD). The mass reduction of the staff took place especially after 01.12.1991, when ECAD was reorganized in new firm "Estonian Air". ECAD recorded 55 bird strikes during 1989-1991. These strikes caused neither aircraft losses nor injuries, but 10 strikes resulted in damages of various degree to aircraft. Only 1 bird strike was included in this review after 17.07.91 - very serious collision 03.08.91 with capital repairs of engine D-30 from Tu-134.

1.Bird Strikes by Impact Location

Distribution of bird strikes by impact location was the following (number of strikes with damage is pointed in brackets): Radome-2; Windscreen-3; Nose-1; Engine-8(5); Wing-7(3); Fuselage-3; Landing gear-7; Tail-1; Lights-2(2); Part unknown -22.

2.Bird Strikes by Aircraft Type

Table 1 shows distribution of incidents by aircraft type and different years.

Aircraft type/Year	1989	1990	1991	Total
Tu-134	10	3	3	16
Yak-40	12	4	2	16
An-2	3			3
Unknown	8	8	4	20
Total	31	15	9	55

Decrease of bird strikes number can be explained by the following reasons:

-dropping of aircraft movements due to raising of ticket prices and absence of fuel;

-stopping of aviation-chemical works in agrolandscapes with use of aircraft An-2;

-worsening of count quality as consequence of more careless relation of aerodrome staff to their official duties due to numerous economical problems.

On the other hand, Estonian airports in 1990 have became international ones. Now Estonian aircraft carry out regular flights in capitals of Finland, Sweden, Hungary and Frunkfurt A M. Number of charter flights by little aircraft increased very considerably.

3. Bird Strikes by Phase of Flight

There is a great number of incidents, when only died birds were found on aerodromes without detail information about collisionsTherefore picture in general is expedient: ON aerodrome -38, NEAR aerodrome-5, EN ROUTINE-4, unknown-8.

Incidents took place on Tallinn aerodrome and its vicinity -30(54,5%), Kuresaare-6(10,9%), Kärdla-2(3,6%)-both in 1990, Tartu-1(1,8%). In 1 collision it were registered on the following aerodromes: Pulkovo (in 1990) and all the rest in 1989: Borispol, Rostov-on-Don, Cheliabinsk, Krivoi Rog, Krasnodar, Adler. 2 incidents were fixed on routine Kuresaare-Tallinn, 1 in the region of Rapla town, 1 on the routine Tallinn-Borispol, 1 - Pskov-Tartu. Besides that, 1 incident took place at local airport Kihnu on Kihnu island in Riga Gulf and another one on landing point for aviation-chemical works in Kungla (North-Eastern Estonia).

Totally, 45 (81,8%) bird strikes occurred in Estonia, 7 (12,7%)-abroad, 3 (5,5%) - unknown.

4. Bird Strikes by Altitude

Distribution of incidents by altitude was the following: 0-100 m-41 (74,5%), 101-400m-5 (9,1%), 401-1000m-1 (1,8%), 1001-2000m-2 (3,6%), unknown -6 (10,9%).

5. Times of Day and Year when Bird Strikes Occur

Distribution of incidents by time of day was the following: night (00.01-06.00)-2 (3,6%); morning (06.01-12.00)-21 (38,2%); day (12.01-18.00)-15 (27,3%); evening (18.01-24.00) -12 (21,8%); unknown - 5 (9,1%).

Table 2

Year/month	1	2	3	4	5	6	7	8	9	10	11	12	
1989	2				4	3	7	12	2	1			31
1990	1	1	1		1	1	7	2	1				15
1991			2		2	4	----	1	----	----	----	----	9

Table 2 shows distribution of incidents by months in different years. More than two thirds of the strikes occur during summer months (i.e. July and August), the peak month has been August in 1989, July in 1990 and unknown month in 1991, because data for the last years are uncomplete.

6. Birds Involved in Strikes

Table 3

Latin name	English name	ICAO category	Number of strikes
Anas L.	Duck	B	1
Anas platyrhynchos	Mallard	B	2
Apus apus	Swift	A	2
Vanellus vanellus	Lapwing	B	1
Laridae	Gull	B	7
Larus ridibundus	Black-headed Gull	B	4
Larus argentatus	Herring Gull	B	2
Larus canus	Common Gull	B	3
Columba L.	Pigeon	B	1
Acc. nisus sive Flconid.	Sparrow Hawk or Falcon	B	1
Perdix perdix	Partridge	B	1
Passeriformes excluding	Corvidae	B	5
Riparia riparia	Sand Martin	A	6
Hirundo rustica	Swallow	A	2
Delichon urbica	House Martin	A	3
Hir. rust. sive Del. urb.	Swallow or Martin	A	3
Alauda arvensis	Skylark	A	2
Corvus corone cornix	Hooded Crow	B	1
Strigidae L.	Owl	B	3
Unknown species or group		?	6
Total			55

Gulls were involved in 32,7% of incidents where the bird species was known, swallows and martins in 24,5% of incidents. Participation of owls in strikes - 6,1% is considerably higher, than earlier.

During one week at the middle of August 1989 some thousand individuals of Sand Martins (Riparia riparia) were resting on runway of Kuresaare aerodrome. About 10 Martins perished during each take-off of aircraft Yak-40.

There were not bird strikes involved birds over 1,8 kg.

7. Damages Caused by Bird Strikes

Number of bird strikes with damages formed 18,2% (10 from 55). Total 5 engines, 2 lights and covering of 3 wings were damaged, all on different aircraft. Among 5 engines, 4 engines D-30 were repaired on Tu-134A and 1 engine AI-25 on Yak-40. In 5 incidents with damaged engines, 2 engines were replaced completely and in 3 incidents only separate damaged blades were replaced without capital repairs.

Twice authority of ECAD was forced to direct the additional aircraft in transit airports for removal of waiting passengers. It were in Borispol 15.05.89 and in Cheliabinsk 04.07.89. In Cheliabinsk aircraft stood under repair during 112 hours, in Adler (Sochi) 12.10.89 - 55 hours. The total standing idle (demurrage) of aircraft formed about 200 hours.

It is very difficult to estimate the total damages from bird strikes. According to preliminary data, it are equal about 300 000 roubles in old prices.

Table 4 shows list of the most serious bird strikes with Estonian aircraft in 1989-1991.

Table 4

The most serious bird strikes with Estonian aircraft in 1988-1991

N	Date	Aircraft type	Bird species	Number of birds	Airport or routine	Phase of flight	Speed (km/h)	Altitude (m)	Damaged part of aircraft
1.	13.01.89	Tu-134A	Passerines	5-10	Borispol (Kiev)	Taking -off	320	100-200	3 blades in left engine replaced
2.	06.05.89	An-2	Passerines	1	Pskov-Tallinn	en rout.	180	300	bird went through wing
3.	15.05.89	Tu-134A	?	1	Tallinn-Borispol	?	?	?	engine replaced demurrage-5 hours
4.	04.07.89	Tu-134A	Passerines	flock	Cheliabinsk	Descent or approaching	?	?	3 blades in right engine replaced engine completely demurrage-112 hours
5.	08.08.89	Yak-40	Gull ?	1	Kuresaare-Tallinn	Descent	400	1600	dent on front edge of right wing 10 x 10 sm and in depth about 3 mm
6.	17.09.89	Tu-134	Duck ?	1	Krasnodar	Descent	280	90	left main light broken, demurrage - about 10 hours
7.	12.10.89	Tu-134	?	1	Adler (Sochi)	Descent	320	400	dent 30 x 40 sm and in depth 4 sm on front edge of left wing
8.	18.03.90	Yak-40	Dark bird of mean size	1	Tallinn	Climbing	280	300	small dent on front edge of right wing
9.	12.07.90	Yak-40	Gulls	4	Kärdla	Taking-off	170	0-2	right light destroied. right engine damaged in 4 places; 1 dent 0,5x1 mm on blade of outer directing apparatus; 3 dents on blades of 1st stage of low pressure compressor: 2 dents by 0,5x1 mm and 1 dent - 2x1 mm
10.	03.08.91	Tu-134A	?	1	?	?	?	?	engine replaced completely

SOVIET BIBLIOGRAPHY ABOUT AVIATION AND RADAR ORNITHOLOGY

1990-1991

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ABSTRACT

This bibliography is continuation and more accurate definition of working paper 22 at BSCE 20. Bibliography covers 33 reports of 23 soviet specialists and 2 report of 2 ornithologists from former GDR.

Khartunov O.A. Ornithological situation in Stavropol airport. -Ecological problems of Stavropol Territory and neighbouring territory. Reports of regional scientific-practical conference 4-6 October 1989. Stavropol, 1989. Pp. 280-281. Rus.

Borodin O.V. Results of ornithological investigations of Ulianovsk airport. -Ornithological researches in Middle Povolzh'e (environs of Volga river). Kuibyshev State University. Kuibyshev, 1990. Pp.65-68. Rus.

Il'ichev V.D. Bioacoustic facilities for birds scaring away from important objects. -The fundamental sciences - for national economy. Moscow, 1990. Pp. 305-306. Rus.

Sokolov V.Ye., Il'ichev V.D., Yemel'yanova I.A. Mammals and birds, deteriorating technical facilities and constructions. Series "Biodeterioration". Moscow, "Nauka", 1990. 240 p. Fig. 116, Bibl. 79 titles. 32 maps of bird species range, 24 maps of mamal species range. ISBN 5-02-005870-X. Edition -900 copies. Rus., summary and contents in Engl.

Engineering ethology: bioacoustic and biolinguistic of birds. Collection of scientific papers. USSR Academy of Sciences. A.N.Severtzov Institute of Evolutionary Animal Morphology and Ecology. Editor Dr V.E.Yacoby. Moscow, "Nauka", 1991. 199 p. ISBN 5A-02-00297-4. Rus., summary in Engl.

This book includes the following papers, directly dedicated aviation and radar ornithology:

Jacoby V.E. Ecology-ethological factors in aviation ornithology 17-25
Nikol'sky I.D. Accustomation to repellent irritants as the behavioural adaptation of birds 26-32
Jacoby V.E. To use of means directed to avoiding of collisions between aircraft and birds 47-50
Biryukov V.Ya. Minimisation of bioacoustic synthesizers 57-60

Biryukov V.Ya., Nechval N.A. Probabilistic model for description of bird species composition in collisions with aircraft 60-63

Biryukov V.Ya., Nechval N.A. Possible damage due to bird strikes and reaching of optimal decision 63-67
Il'ichev V.D., Biryukov V.Ya., Nechval N.A. The stohastical model of biodeterioration situation caused birds 68-74
Nechval N.A. Characteristics of defence means from biodeterioration and statistical problems of its analysis 74-80
Nechval N.A., Biryukov V.Ya. Determination of the upper limit of confidence coefficient of bird strikes in one movement of aircraft (taking-off or landing) 80-83
Nebabin V.G., Kotyatsy M.I. Use of radars in bird strikes avoiding 83-88
Shergalin J.E. Industrial-transport factors and noise level in anthropogenous bird biotopes in Northern Estonia 148-153
Rogachev A.I. The modern tendencies in aviation ornithology 166-168
Shurakov S.A. Use of small bioacoustic unit (BAU) in Perm airport "Bol'shoe Savino" 168-169
Shergalin J.E. The analysis of the meteoconditions of the birds' strikes with an aircraft 169-173
Wernicke P. Aviation ornithology on former territory of GDR 174-176
Erdmann F. All-the-year-round birds' count in agrolandscapes of former GDR 176-180
Lashtabega Yu.O. About destruction of Corvidae nesting colonies in Krasnodar airport 181-182

Bird behaviour control and bird protection. Materials of seminar on problems of bird behaviour control and bird protection (14-18 November 1988, Puschino). Moscow, 1990. 181 p. Fig. 12, Tabl. 11, Bibl. 131 titl. Editor Dr B.M.Zvonov. Edition - 400 copies. Rus.

This book includes the following papers, directly dedicated aviation and radar ornithology:
Il'ichev V.D. The strategical directions of engineering ethology and development of ecological means of bird behaviour control on the bioacoustic base 3-11

Zvonov B.M. The theoretical and practical bases of acoustic repellent bird calls' synthesis 11-15
Prokopenko S.P. Experience of semiwild keeping and birds of prey use as biorepellents 92-94
Poluda A.M., Prokopenko S.P. Use of trained birds of prey, as one of methods in bird behaviour control 121-129
Shergalin J.E. Peculiarities of the birds' behaviour, which perform special danger for aviation during their approach with aircraft 130-133
Shergalin J.E. Control over numbers of the protected bird species in the area of Estonian airfields 133-137
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Yenaleev I.R. Peculiarities of the Goshawk use as a biological repellent on the airfield and fur farm 142-149
Zhurminsky S.D., Kotyatsy M.I., Shtirbu V.I. Ornithological situation in the region of Kishinev airport 149-154
Biryukov V.Ya. Method of ratsional digital encoding of bird acoustic signals on elements of microprocessor's technics 159-166
Nechval N.A. About comparison of intensities and construction of prediction interval for bird strikes numbers on the base of former data 167-173
Biryukov V.Ya., Nechval N.A. Study of statistics in correlation between bird strikes number and aircraft movements number 174-179

SERIOUS BIRD STRIKES TO CIVIL AIRCRAFT 1989-1991

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SUMMARY

The Paper contains a sample of summarised accidents and more serious incidents due to birc strikes in the years 1989-1991. The paper is divided into three sections:

- Transport aeroplanes over 5,700 kg and business jets
- Aeroplanes of 5,700 kg and below
- Helicopters.

The data sample is too small for any in-depth analysis but engine ingestion is clearly the critic area of transport aeroplanes. The windshield appears to be the vulnerable area of general avi aircraft and helicopters. The paper lists previous similar publications.

The Author would welcome any new or additional information which has not been included wit the paper. A marginal line shows alterations between Issue 1 (distributed at Meeting) and Issu

1 Introduction

A number of serious bird strike accidents and incidents occur each year throughout the world. This paper attempts to detail these events obtained from the following major sources:-

- UK Reporting System 1989/90/91
- Flight Safety Foundation Bulletin 1990/1
- Lloyds List 1990/91
- European Reporting Systems
- ICAO IBIS Significant Bird Strike List - 1989/90
- Miscellaneous Publications, including Flight International.

2 Scope

The term 'serious' for the purposes of this Paper includes:

- loss of life
- injury to occupants
- destruction of aircraft
- loss of, or damage to, more than one engine
- damage to one engine, together with ingestion in another engine
- uncontained engine failure
- fire
- significant sized holes, eg windshield, nose, radome
- major structural damage
- particularly unusual or dangerous features, eg complete obscuring of vision, multiple or significant system loss, helicopter rotor or transmission damage.

The paper has been divided into three sections:

- Transport aeroplanes over 5,700 kg and business jets
- Aeroplanes of 5,800 kg and below
- Helicopters.

The data sample is too small for any in-depth analysis. Fatal accidents have a box round the first line.

3 Previous Papers

Similar papers covering earlier years have been published as follows:

- 1912 to 1982 — WP16 and 16A BSCE 16, Moscow August 1982
- 1981 to 1984 — WP27 BSCE 17, Rome October 1984
- 1984 and 1985 — WP4 BSCE 18, Copenhagen May 1986
- 1985 to 1987 — WP22 BSCE 19, Madrid May 1988
- 1987 to 1989 — WP29 BSCE 20, Helsinki May 1990

TRANSPORT AEROPLANES OVER 5,700 KG AND BUSINESS JETS

DATE	AIRCRAFT/ ENGINE	REGN	LOCATION	INJURY
11 Jan 89	*B737 (CFM56)*	*VH-TAH*	*Australia*	-

Both engines suffered from damage during take-off run. Precautionary landing. Birds were starlings *(Sturnus vulgaris 80 gm)*.

31 Jan 89	*DC10 (CF6)*	*PH-MBT*	*Amsterdam, Netherlands*	-

At rotation, 175 kts, the aircraft struck a group of Lapwings *(Vanellus vanellus 215 gm)*. Aircraft returned due to vibration. One blade damaged in Engines 1 and 3.

26 Feb 89	*DC10 (CF6)*	*G-MULL*	*Freetown, Sierra Leone*	-

At 135 kts during the landing roll while using reverse thrust there was a slight thrust loss. A static engineer entered the flight deck and informed the crew that Engine 3 was on fire. Taxied clear of runway and stopped. Both fire bottles discharged, extinguishing fire. Taxied to stand and passengers disembarked. Debris started grass fire at runway threshold. Severe LP fan damage Bird seen to run across runway just after touchdown. Feathers found in engine tail pipe, species unknown.

13 Apr 89	*B747*	*ZS-*	*Windhoek, S Africa*	-

Abandoned take-off run after bird flew into engine. A number of tyres deflated.

25 May 89	*A310 (CF6)*	*VT-*	*Delhi, India*	-

Struck vulture at 4,000 ft shortly after take-off. Nose, pressure bulkhead and radar extensively damaged.

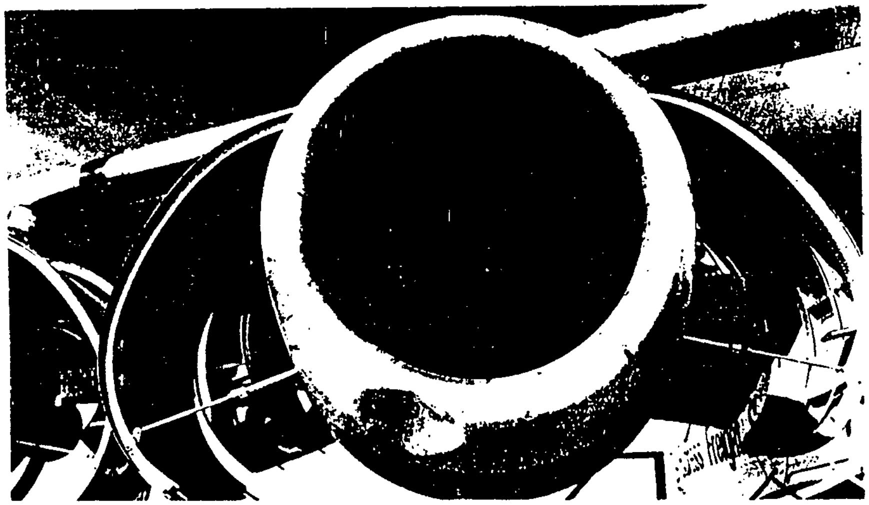
31 May 89	*B737 (CFM56)*	*G-BNNK*	*Venice, Italy*	-

At rotation multiple gull strikes. Captain's ASI fell to below 60 kts, airframe vibration. Engine parameters appeared normal apart from Engine 2 oil contents falling from 80-50%. No 1 Flight Attendant reported high noise level. Due to Engine 1 vibration level increased form 1½-2. Decided to return. Captain flew descent, First Officer took over on finals. Oil contents indication returned normal on finals. First Officer was on first flight in -400 series.

07 Jun 89	*BAe 146 (Alf 502)*	*G-TNTJ*	*Genoa, Italy*	-

At rotation on a midnight take-off from runway 11, a huge flock of gulls rose from the surface and hit many parts of the aircraft. All engines lost power and No 3 had to be shut down. Climbed to 1,000 ft for circuit and overweight return. There were 57 strikes to airframe from the Mediterranean herring gulls *(Larus argentatus 1 kg)*. Three engine nose cowls damaged and all 4 engines changed as follows:

Engine 1 - most fan blades damaged.
Engine 2 - two fan blades broken with penetration of casing, core damage. Fuel oil exchanger mountings adrift, both fire bottles found blown.
Engine 3 - three fan blades bent, most have tip bends, HP compressor stators bent.
Engine 4 - two fan blades badly bent, core damage, bypass duct stators 60% separated. There were various airframe dents.



28 Jun 89 ***B737*** ***VT-*** ***Delhi, India*** ***Co-pilot injured***

Flock of birds smashed into cockpit injuring co-pilot and causing extensive damage. Aircraft returned. Damage cost approximately $100,000.

04 Jul 89 ***A300 (CF6)*** ***D-AHLC*** ***Munich, Germany*** -

At about 20 ft and 150 kts aircraft struck a flock of gulls. The aircraft diverted due to vibration on Engine 1. Damage to fan blades of both engines.

10 Aug 89 ***A320 (CFM56)*** ***VT-EPE*** ***Delhi, India*** -

During final approach, 2,500 ft, 250 kts, a vulture hit the top of the captain's panel of the windshield, this was cracked but not penetrated and frame distorted. The impact caused loss of information on four of the six CRT displays and Engine 2 LP fuel valve cut out, causing engine to shut down. Single engine procedure flown without any information on the screen about the failure. After landing the captain's navigation screen also failed. Bird identified from two feathers jammed in windshield mounting as an Indian white-backed vulture *(Gyps bengalensis 4.5 kg)*.

10 Sep 89 ***B737 (J8D)*** ***D-ABMF*** ***Sestri, Italy*** -

Just after take-off at 135 kts a flock of gulls was struck. Blades were damaged in both engines as well as the stabiliser leading edge.

06 Oct 89 ***A320*** ***F-GGEC*** ***Nr Nimes, France*** -

Descending through 9,000 ft at 320 kts windshield damaged by unknown birds.

27 Oct 89 ***A300 (CF6)*** ***F-BVGD*** ***Entzheim, France*** -

During take-off run struck flock of Rock doves *(Columbia livia 400 gm)*. Precautionary landing. One fan blade on each engine damaged.

28 Oct 89 ***A300 (CF6)*** ***F-BUAI*** ***Entzheim, France*** -

During take-off run struck flock of Rock doves *(Colombia livia 400 gm)*. One fan blade damaged on Engine 1 and four on Engine 2.

30 Oct 89 ***Fokker F27*** ***S2-ABP*** ***Jessore, Bangladesh*** ***Minor***

In the climb at 4,200 ft, 158 kts, co-pilots side windshield was shattered. Co-pilot unconscious. Aircraft returned.

20 Nov 89 ***A300 (CF6)*** ***I-BUSL*** ***Rome, FUI, Italy*** -

During the take-off run a flock of Lapwings *(Vanellus vanellus 215 gm)* was struck, damaging the fans of both engines. A precautionary landing was made.

06 Jan 90 ***B737 (CFM56)*** ***G-OMBM*** ***Prestwick, UK*** -

Just after take-off at 20 ft, struck flock of Black-headed gulls *(Larus ridibundus 275 gm)*. Ingestion in both engines, due to high vibration one throttled to idle. Precautionary landing. Found 10 fan blades damaged.

29 Jan 90 ***B747 (CF6)*** ***N1298E*** ***Amsterdam, Netherlands*** -

At 155 kts during the take-off run the aircraft struck a Grey heron *(Ardea cinerea 1.5 kg)*. After dumping 76 tons of fuel the aircraft returned. Left cabin windows 4, 5 and 6 were damaged and had to be changed.

28 Apr 90 ***BAC 1-11*** ***G-BJMV*** ***Gerona, Spain*** -

At 10 ft, 152 kts the aircraft struck a group of Herring gulls *(Larus argentatus 1 kg)*. The landing gear down-lock jack was damaged, resulting in loss of fluid on No 1 hydraulic system.

22 Jul 90 ***DC9 (JT8D)*** ***EC-BYG*** ***Nr Madrid, Spain*** -

While descending through 13,000 ft, 320 kts the aircraft struck a Bustard *(believed - Tetrax tetrax 810 gm)*. The radome was holed, damaging the radar and nose gear well. The aircraft was out of service for one month and repairs cost $60,000 US Dollars.

25 Jul 90 | ***B707 (JT3D)*** | ***ET-ACQ*** | ***Addis Ababa, Ethiopia*** | -

Abandoned take-off following suspected bird strike on Engine 3. Overran runway down a 60 ft embankment and broke in half. Runway was damp. Five crew escaped, constructive total loss.

20 Aug 90 | ***B747 (JT9D)*** | ***ZS-SAT*** | ***Heathrow, UK*** | -

Just after V_1 the aircraft struck three Canada geese *(Branta canadensis 3.6 kg)*. The Captain saw the birds and attempted to rotate the aircraft slightly earlier than usual and scraped the tail section of the fuselage on the runway. Fuel was jettisoned and the aircraft returned. Flap canoe fairing damaged by bird impact and rear fuselage skin, rear pressure bulkhead and APU doors damaged by tail-scrape. Three dead birds on runway. These geese normally cross the distant extended centre line but on this occasion crossed the centre of the runway. Patrols were busy on another part of the airport with flocks of gulls.

31 Aug 90 | ***DC9 (JT8D)*** | ***9Y-THQ*** | ***Crown Point, Trinidad*** | -

Just after lift-off at 140 kts, a flock of Ducks *(Anserspp)* were struck. Engine 2 suffered severe compressor damage. Precautionary landing, Engine 1 also affected but not damaged.

07 Oct 90 | ***B737 (JT8D)*** | ***OO-SDO*** | ***Nr Brussels, Belgium*** | -

Climbing through 6,000 ft at 250 kts unknown birds were struck. As all engine parameters were normal, the flight continued to destination. Engineers, on arrival, found damage to both engines.

19 Oct 90 | ***Fokker F28 (Spey)*** | ***SE-DGF*** | ***Nr Visby, Sweden*** | -

While climbing through 250 ft at 150 kts, the radome was holed after striking unknown birds. A precautionary landing was made.

24 Nov 90 | ***B757 (RB211)*** | ***G-RMRB*** | ***Budapest, Hungary*** | -

During take-off run, just prior to rotation at 130 kts, struck a flock of gulls. Engine vibration in amber band, power to idle on Engine 1. Returned using Engine 2. Found several distorted blades and hole in acoustic lining on Engine 1. Much bird debris found in Engine 2.

02 Dec 90 | ***BAe 125 (TFE731)*** | ***OH-JET*** | ***Karachi, Pakistan*** | -

At 2,000 ft, 175 kts on the approach a Vulture was struck, causing shutdown of one engine. Two fan blades separated, others badly bent. Air intake attach bolts loosened, oil line broken at pump and oil filter by-pass indicator had popped out. After landing the APU could not be started.

06 Feb 91 | ***L1011 (RB211)*** | ***A40-*** | ***Sheraz, Iran*** | -

During the take-off run a flock of 'black' birds rose from the runway causing a series of impacts. Engine 3 overtemperatured so was shut down. Engine 1 showed reduced power and full scale vibration and was shut down after 2½ minutes. A single engine circuit and landing was made. Engine 1 suffered damage to 13 fan blades with signs of ingestion by 10 birds. Engine 3 damage to compressor rotor blades indicated ingestion by 3 birds. Bird debris identified as mixed flock of

Hooded crows *(Corvus corone 530 gm)*, Jackdaws *(Corvus monedula 234 gm)* and Ravens *(Corvus corax 1.1 kg)*.

21 May 91 | ***DHC-7 (PT6)*** | ***G-BOAW*** | ***Nr Brussels, Belgium*** | -

At 3,000 ft, 200 kts on the approach a loud thud was heard. After landing 12" x 4" hole found in right wing leading edge.

24 Nov 91 | ***DC10*** | ***N-161NS*** | ***Glasgow, UK*** | -

Shortly after rotation the aircraft suffered a multiple bird strike. ATC observed smoke and flame from Engine 3. Shutdown and fire extinguished. Found broken blade had exited through bottom cowling. Birds remains on runway were Common gulls *(Larus canus, 420 gm)*.

07 Dec 91 | ***B747 (JT9D)*** | ***N203AE*** | ***Heathrow, UK*** | -

Although the crew were not aware, Black-headed gulls *(Larus ridibundus 275 gm)* were struck on the approach. Blood marks on left wing, main gear and Engine 2. Engine 1 was damaged with bent fan blades. Dead bird in left flap.

HELICOPTERS

DATE	AIRCRAFT/ ENGINE	REGN	LOCATION	INJURY
05 Dec 89	*Bell 206 Jet Ranger*	*G-CULL*	*Nr Norwich, UK*	-

While en-route at 300 ft, 90 kts a Common gull *(Larus canus 420 gm)* shattered the left windshield: the wind-blast blew out a side window.

22 Jan 90	*Bell 206 Jet Ranger*	*G-CULL*	*Nr Shepton Mallet, UK*	-

In cruise at 300 ft and 100 kts, a gull struck the top right hand quarter of windshield making a large hole. Blood and remains entered cabin.

21 October 1990	*AS355 Ecureuil 2*	*OE-FXH*	*Nr Petronell, Austria*	-

While en-route at 120 kts, 450 ft during a medical flight the helicopter struck a bird causing a 15 cm hole in the nose and scattering debris in the cabin.

15 Aug 91	*Sikorsky S76*	*G-BOND*	*Aberdeen, UK*	-

While en-route at 1,000 ft, 120 kts a gull was seen and avoiding action taken. Unable to avoid it. A fist-sized hole was found in the cockpit roof above co-pilots windshield.

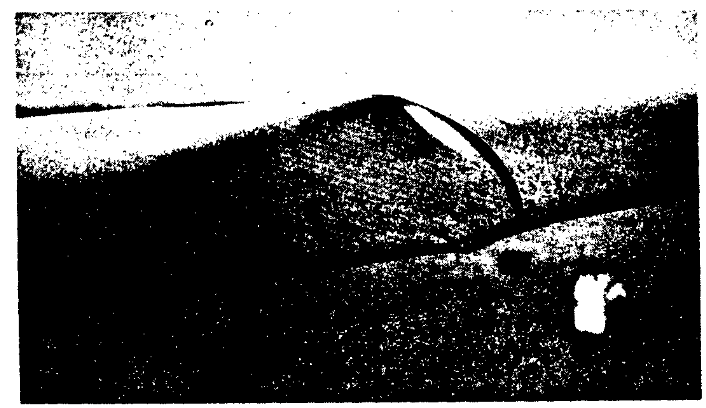
AIRCRAFT OF 5700 KG AND BELOW

DATE	AIRCRAFT/ ENGINE	REGN	LOCATION	INJURY
08 Apr 89	*Cessna 402*	*5H-72B*	*Dodoma, Tanzania*	

At 90 kts during the take-off run the windshield was broken due to a bird strike. Bird species unknown.

24 Jun 89	*Gulfstream AA5*	*G-BLHD*	*Nr Southampton, UK*	

While at about 1,000 ft and 90 kts in the circuit, the aircraft struck a gull which dented the wing leading edge resulting in a large hole at a skin joint.



05 Sep 89	*Cessna 152*	*VH-FUH*	*Nr Archemfield, Australia*	*1 minor*

At 1,500 ft struck Wedge-tailed eagle *(Aquila audax 3.5 kg)*. Windshield shattered causing minc injury to pilot.

28 Nov 89	*Piper PA28*	*XB-ASX*	*Zihuatanefo, Mexico*	*Minor*

At 50 kts during the take-off run the aircraft struck a Buzzard *(Buteo buteo 800 gm)*. It penetrat the windshield causing minor injury.

Jul 91	*P47 Thunderbolt*	-	*Oshkosh, USA*	-

Gull went down carburettor air intake causing loss of power. Just able to glide to airfield.

27 Dec 91	*Piper PA31 Navajo*	*5Y-SRV*	*Masai Mara, Kenya*	*9 killed*

A DC3 had suffered a gear-collapse at the end of its landing run at a game park airfield and the PA31 pilot made a pass over the site (not its destination). The aircraft struck a Vulture which smashed the windscreen killing the pilot. The aircraft crashed killing all occupants. The airfield is approximately 100 miles from Nairobi

28 Dec 91	*Beech 200*	*F-GCTP*	*Paris CDG, France*	-

In climb windshield damaged at 100 ft, 110 kts by Lapwing *(Vanellus vanellus 215 gm)*. Precautionary landing, windshield changed.

1992 SUPPLEMENT

DATE	AIRCRAFT/ ENGINE	REGN	LOCATION	INJURY
26 Jan 92	*Cessna 401*	*5Y-BGW*	*Masai Mara, Kenya*	*7 killed*

Reported by the pilot of another aircraft, the Cessna pilot made a MAYDAY call that he "had a bird strike and would have to make an emergency landing because he was having trouble maintaining control." The pilot of the other aircraft saw the Cessna go into a spin and explode on impact with the ground. The wing tip and fuel tank were found a considerable distance from the main wreckage. The bird was believed to be a Marabou stork *(Leptoptilos crumeniferus 5.9 kg)*.

11 Feb 92	*Enaer Namcu*	-	*Nr Santiago, Chile*	*1 killed*

The fourth prototype of the 2 seat trainer was destroyed killing the test pilot while attempting to land following a bird strike.

CORRECTIONS TO BSCE 20/WP28

'Analysis of Bird strikes Reported by European Airlines 1981-1985'

Owing to the haste with which the Paper was word processed for the Helsinki meeting, a number of errors crept in as follows:

P 263	Summary	- Para 2 first line, rate should be 5.1 not 5.7
P 266	Para 3.1 (c)	- Line 3, rate should be 5.1 not 5.7
P 274	Para 4 (a)	- Line 2, should be 5.1 per 10,000 movements
P 277	Table 2	- Boeing 757, all strikes should be 71 not 7 and the strike rate should be 5.9 not 0.3 - HS Argosy, should in all strikes column be 1
P 278	Table 2	- HS 748, damage rate should be 0.3 not 0.1 - Helicopter total is in hours
P 279	Table 3	- Brussels, total strikes should be 87 not 81 - Mariehamn, should be damage 2, all 41 - in place of 2 - Vaasa, total strikes should be 9 not 7 - Lille, should be 16, 23, 331, 6.9, -, -, 16 - Hyenes, Octeville, delete entry
P 280	Table 3	- Le Harve, should be 8, 3702, 21.6, -, -, 8 - Paris LBG, should have a rate of 8.7 - Corfu, foreign strikes should be 31 not 29
P 281	Table 3	- Eindhoven, should be total 4 strikes - Maastricht, should be total 3 strikes - Under Portugal add: Funchal, Madeira, foreign 2, damage 1, total 2 Lisbon, foreign 30, damage 2, total 30 - Mahon, foreign 17, damage 1, total 17 - Delete entry for Minorca - Angelholm, total should be 22 not 20 - Gothenburg, should be 20 not 19 - Lulea, should have 1 foreign strike
P 282	Table 3	- Aberdeen, national strikes 46 not 54 - Guernsey, national 40, total 40 - Jersey, national 27, total 27 - Moscow, Sheremetyero, 5 European, nil damaging
P 283	Table 3	- Dalaman, total 3, damaging nil - Kano, total 13, damaging 3 - Karachi, total 11, damaging 3 - Las Palmas, damaging 2 not 12 - Nairobi, damaging 13 not 15
P 289	Table 6	- Headings should be 'below 110 g', and '110 g to 1.81 kg' - Propeller, should be total 104 not 10
P 290	Table 7	- Headings should be '1.81 kg to 3.63 kg' and 'over 3.63 kg'

J Thorpe
Author

BSCE 21 / WP 33
Jerusalem 22-27 March 1992

AVIAN COMMUNITY AT ROME INTERNATIONAL AIRPORT OF FIUMICINO. A STUDY FOR BETTER FACING BIRD HAZARD.

by

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ABSTRACT

The avian community of Rome International Airport of Fiumicino has been investigated from 1989 to 1991 with a project commissioned by the Operative Security Division of Aeroporti di Roma Society. Linear Transect Method has been used and more than 1700 daily recording forms were filled. 88 species of birds have been observed, 37 non passerine and 51 passerine. Herring Gull (Larus cachinnans), Black-headed Gull (Larus ridibundus), Lapwing (Vanellus vanellus), Starling (Sturnus vulgaris) and Hooded Crow (Corvus corone cornix) resulted to be the most important species for risk of collision with landing and taking off aircrafts. Circannual data about their localization, number, periods of presence, flocking, habitat and time preferences, responses to scaring devices, etc. have been collected. The complete results of the research are at present used for planning a complete renewal programme of all scaring devices system.

1. INTRODUCTION

The risk of collision with birds in airports presents a complex problem which is often difficoult to resolve. The bulk of all precautionary measures applied are rarely based on in-depth knowledge of bird populations, and therefore, tend simply to reduce the influx of certain species. Moreover, despite the economic cost involved, many of these dissuasive measures have not fulfilled the initial expectations, either because the presence of bird populations in airport zones is due to circumstances not necessary related to the airport itself (migratory routes, feeding grounds, etc.), or because the ecosystems surronding the airport greatly predetermine the species and populations densities found.

It is then clear how important could be to undertake a preliminary ornithological study on the qualitative and quantitative variation of the avian community during the year at an airport. This is essential for the better knowledge of the environmental reality and for a proper planning in the use of scaring measures, in order to try to reduce bird hazard.

Considering this situation, in 1990 the S.O.E., Operative Security Division, of the Aeroporti di Roma Society, commissioned an ornithological study at Fiumicino International Airport. This paper is the summary of the most significant results found during the research.

2. STUDY STRUCTURE

A general examination of faunistic, vegetational and geomorphological characteristics of the study site (the runways area) has been conducted, together with the analysis of the more general environmental characters of the region.

An ornithological study has been conducted using two different methods.

Simultaneously the behaviour of the species at the study site has been investigated.

Presence of potential environmental, climatic, etc. factors affecting bird occupation rhythms has been seeked for.

The estimate of scaring measures has been attempted, and finally, considering the results obtained, we suggested some guide-lines for a more practical study concerning scaring measures and environmental situation, in order to plan bird management at the airport.

3. STUDY AREA

Fiumicino Airport "Leonardo da Vinci" is situated in a wide ope area bordered by the Tyrrhenian Sea to the West, the village c Fregene to the North, Fiumicino town to the South and cultive fields and pastures to the East. The whole airport area is abou 5.000 hectares mostly made by meadows where hay is cultived ar regularly mowed (max. grass lenght = 70 cm). Inside there are runways of 4.143 m (runway 1), 3.500 m (runway 2) and 4.214 (runway 3) respectively.

Inside and around the area there are many drain sewers and wate sheets. East-Northeastwards there is a modern garbage dump, onl a few km away.

The geomorphological structure of the soil is different insic the airport, with the presence of a vegetational cline; from a arid and steppe-like situation nearer to the coast, to a marsh swamp-like situation more Eastwards.

4. STUDY METHODS

Besides the general analysis conducted about the ecological ar environmental reality of the study area, the following methoc have been used for the research:

4.1. Data collecting through a daily recording form, filled t the Security Division staff, previously instructed.

This form, FIG. 1, prepared after several visits at the stuc area, permitted to record data on the most important species. The most important sectors are, besides observation time ar meteoreological conditions, the following:

- Situation observed: Species; No. of individuals (1-10, 11-5(51-100, etc.); Habitat (runway, taxi-ing way, meadow) Localization (using a coordinate system prepared behind the for wich gives the localization inside squares 700 m x 700 m).

- Scaring measure adopted: Kind (Shell crackers, acoustica device, etc.); Intensity (No. of shell crackers, trait c acoustic system on, etc.).

- Outcome of the device: Escape (Yes/No); Flight direction.

These sectors are repeated several times on the form to allc separation between single observations.

The forms have been used between 23th March 1989 to 4th Februa 1991. More than 1700 filled forms have been collected in 6ε days.

4.2. Linear Transect Method

This ornithological method is perfectly suitable for the homogeneous environment of the airport. For a complete description see JARVINEN & VAISANEN 1973. Data collected during the transects have been worked out obtaining the following parameters which describe the avian community from the ecological point of view:

d = density (No. of individuals per species/area)

S = species richness (number of species in the study area)

f = relative frequence (relative frequence of individuals of a species/total No. of individuals of all species).

% n.P. = % non Passerines. The No. of non Passerine birds is lower in the poorer ecological communities.

ND = No. of dominant species (No. of species with $f > 0.05$)

H = species diversity ($H = D \ln D$). Diversity increases with the maturity degree of the community.

J = equitability index ($J = H/H\ max$, $H\ max = \ln S$). It indicates the level of realization of maximum possible diversity inside the community.

The transects selected at the study area and covered on foot twice a month were situated along the meadows between the runways and the taxi-ing ways.

Transect no. 1 (runway 1): Lenght = 4.143 m; Surface = 82.86 ha
Transect no. 2 (runway 2): Lenght = 3.143 m; Surface = 62.86 ha
Transect no. 3 (runway 3): Lenght = 4.429 m; Surface = 88.58 ha

The counts were carried on between February 1990 to January 1991, collecting 200 hours of observations and 281.160 km covered on foot.
A 10 x 42 Leica Binoculars has been used for the survey.
Covering the transects by car has been also attempted, but too many informations are lost with this method.

5. RESULTS

The most significant results of the research are present here. Because of obvious reasons these data are only a sample the complete results obtained (for the complete report s MONTEMAGGIORI 1991).
88 species of birds have been observed in the airport duri the study period, 37 non passerine and 51 passerine. Of each c the present situation inside the runways area, the outcomes the scaring measures, the behaviour and the level of possib hazard have been described and discussed, together with a conci morphological description, the national and local movements the species and their ecology.
5 species resulted the most dangerous for potential risk collision: Herring Gull (Larus cachinnans), Black-headed Gu (Larus ridibundus), Lapwing (Vanellus vanellus), Starli (Sturnus vulgaris) and Hooded Crow (Corvus corone cornix).
Their daily presence showed as monthly total number of observ individuals and as % of days of presence in each month is sho (FIG. 2, 3).
Flock numbers and the average number of birds per flock of ea species have also been recorded.
The resumed localization along the runways of the 5 species, a its magnitude, is showed in FIG. 4.
FIG. 5 presents habitat preference (runway, taxi-ing wa meadow) and 24 hours-time preference of one of the abo mentioned species: the Herring Gull.
As an example of the results obtained about the outcomes of t scaring measures, Fig. 6 shows the case of Lapwing.
Finally, the descriptive parameters of the comple ornithological comunity, obtained with the Linear Transe Method, are resumed in TAB. I.

6. DISCUSSION

Data collected allowed quite a satisfactory and complete pictu of the ornithological reality inside the airport. The avia community wich inhabit Fiumicino Airport results to be wel diversified, with many small species living inside the area ar only 5 species seriously involved in security problems.
Herring Gull and Black-headed Gull are present with large flock all year round, while Lapwing and Starling are only winterir species. Hooded Crow is resident in the area, but its number i usually very low.
Both Herring and Black-headed Gulls seem to use the airpor basically as a resting site, particularly during the morning, an they prefer the runways and the taxi-ing ways for day-roosting Starling and Lapwing, on the contrary, use the airport as feedin ground, and stay on the meadows.

In any case the presence of all such species along the runways during the night seems to be extremely rare.

The favourite areas where Gulls have been observed during the year are the ends of the runways, probably because they are less disturbed by air-traffic. Lapwing and Starling are instead more attracted by dump meadows, wich are confined along runways 2 and 3. Hooded Crow localization is more scattered inside the whole area.

Species responses to scaring devices (gas cannons, acoustical devices, shell crackers and direct inspections) may vary according to periods of the year and meteoreological conditions. The use of gas cannons has not been fully investigated. In any case none of the measures used at present gives completely satisfactory results.

7. CONCLUSIONS

The knowledge of periods of presence, numbers, areas, habitat preference and favourite periods during the day by the different species, together with their responses to the scaring devices, is a very important and useful "tool" for better facing the airport security problems.

This background information results to be essential for a serious line of action to reduce the risk of bird strikes in the airport.

On the basis of that, Fiumicino Airport has recently started a programme of complete renewal of its scaring devices. This involves, among others, the innovative use of a remote controlled video system, able to automatically identify birds' flocks along the runways, and to switch on different scaring devices only when and where they are really necessary, so reducing the accostuming problems.

8. REFERENCES

JARVINEN O. & VAISANEN R.A., 1973. Species diversity of Finnish Birds. I Zoogeographical zonation based on land birds. Ornis Fennica 50: 93-125.

MONTEMAGGIORI A., 1991. Relazione finale di studio sui ritmi di occupazione ornitica dell'Aeroporto "Leonardo da Vinci" in un ciclo annuale. Unpublished report, S.O.E., Aeroporti di Roma, Aeroporto di Fiumicino: 231 pp.

FIGURE 1. The recording form used at Fiumicino Airport.

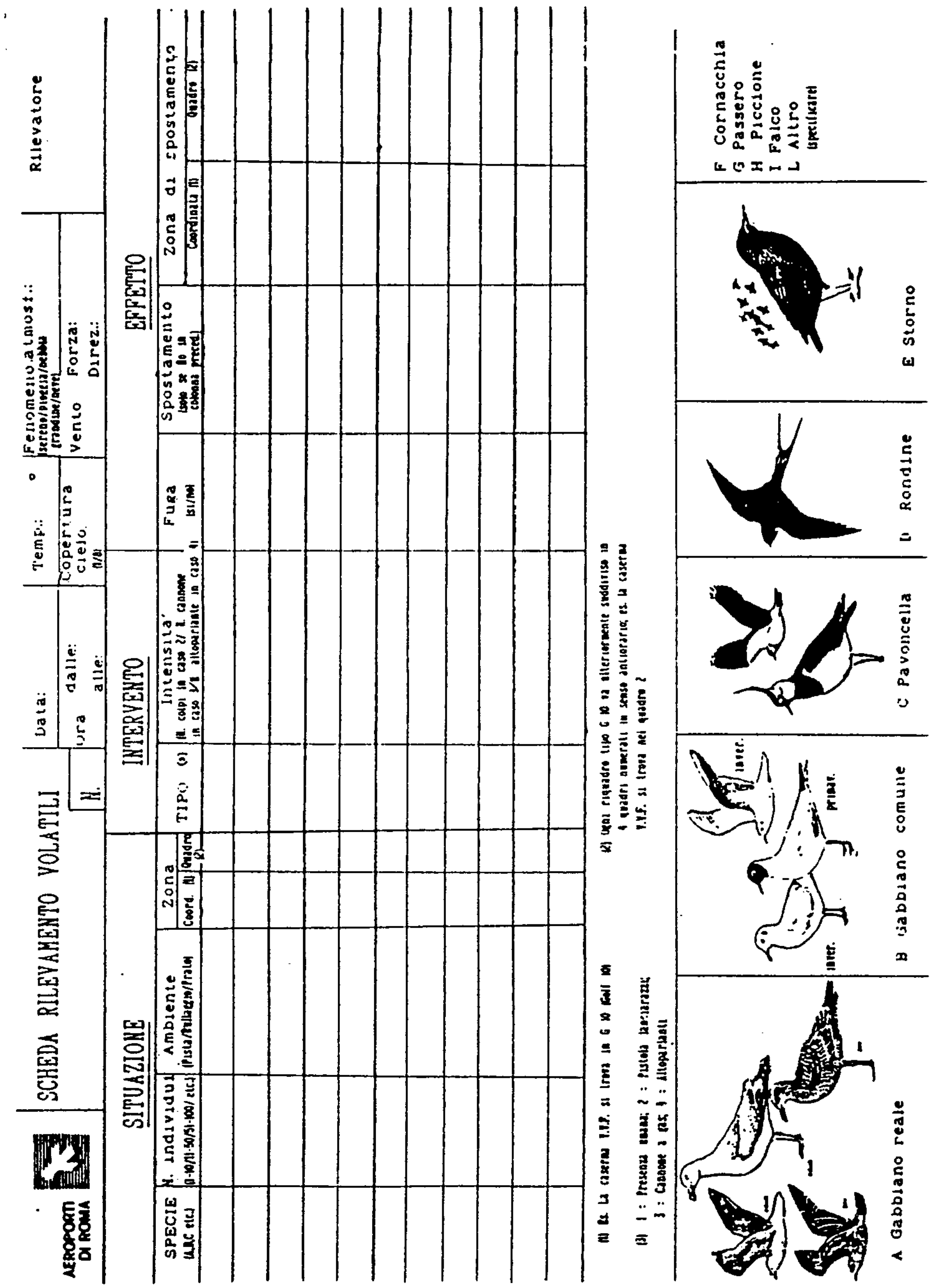


FIGURE 2. Presence of 4 species at Fiumicino Airport (No. of individuals).

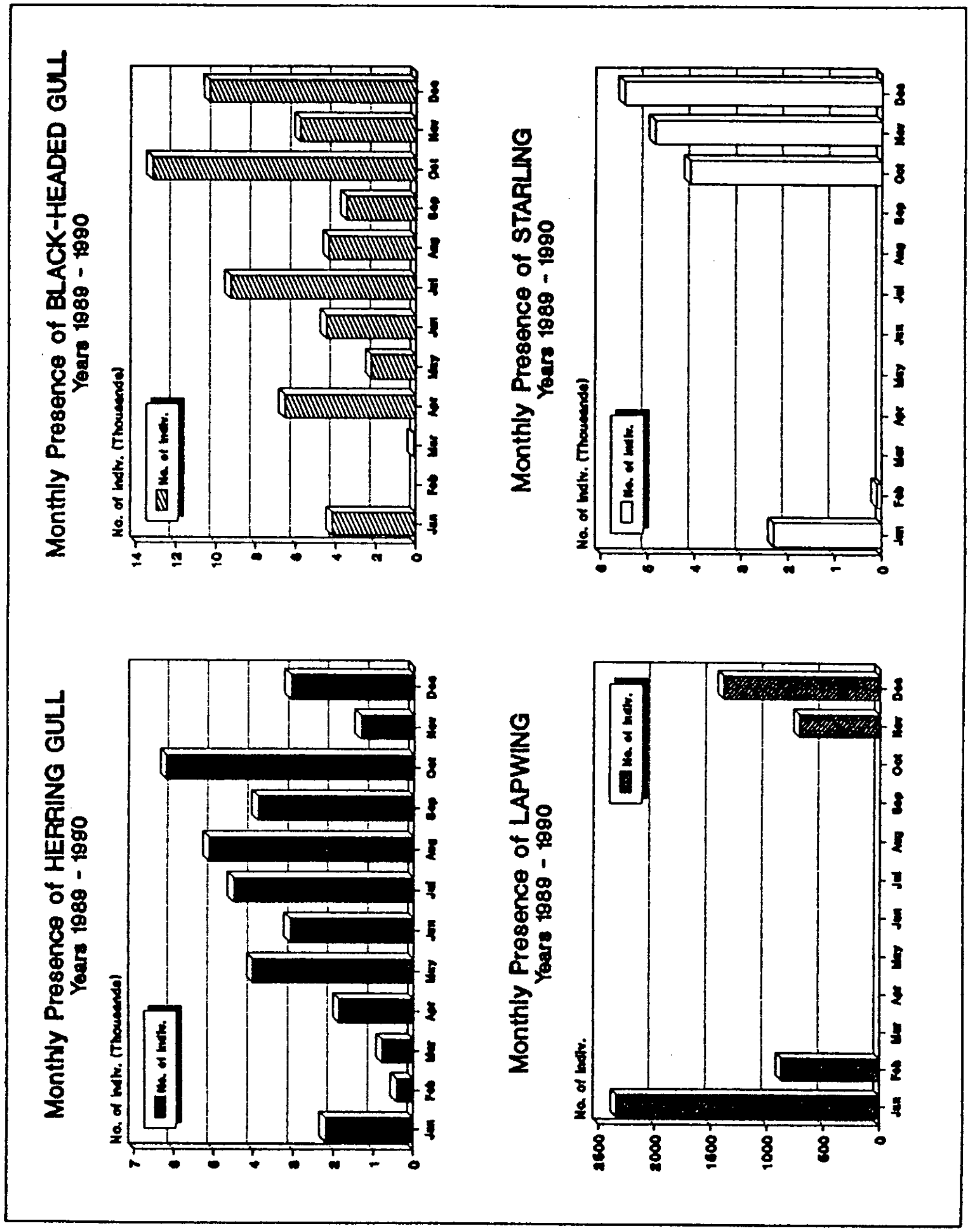


FIGURE 3. Presence of 4 species at Fiumicino Airport (% of day in each month).

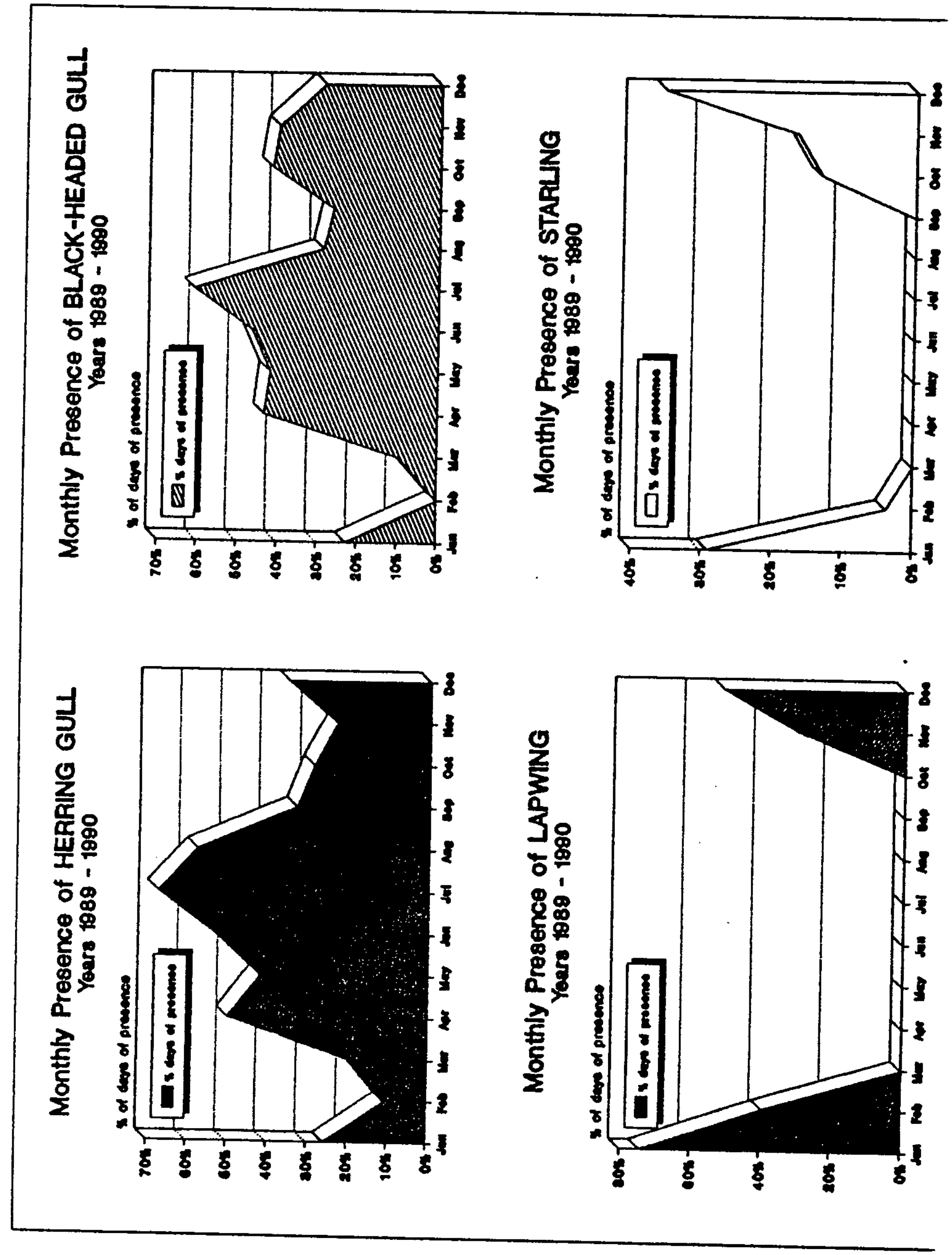


FIGURE 4. Localization of the most important species along the runways and its magnitude.

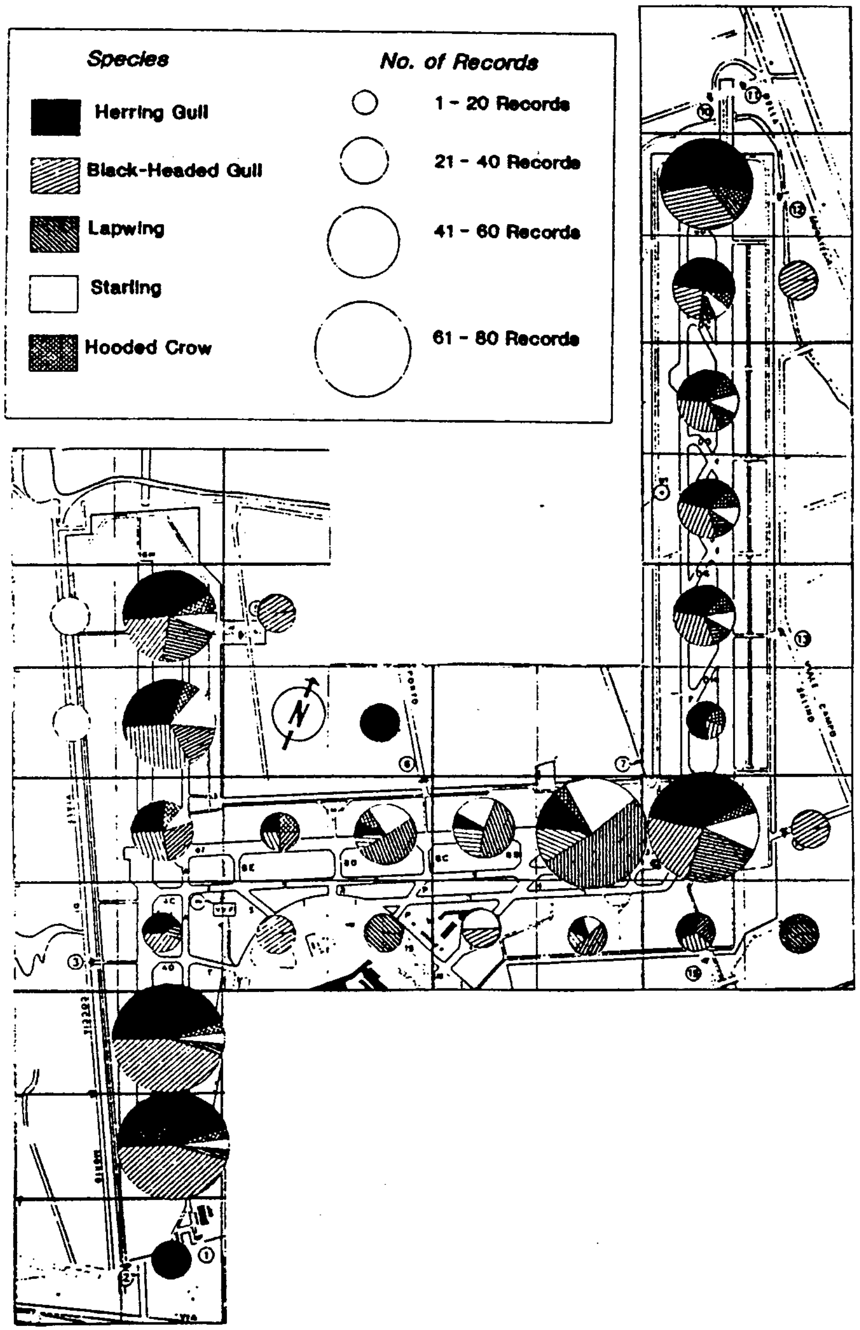


FIGURE 5. Habitat and 24 hours-time preference of HERRING GULL.

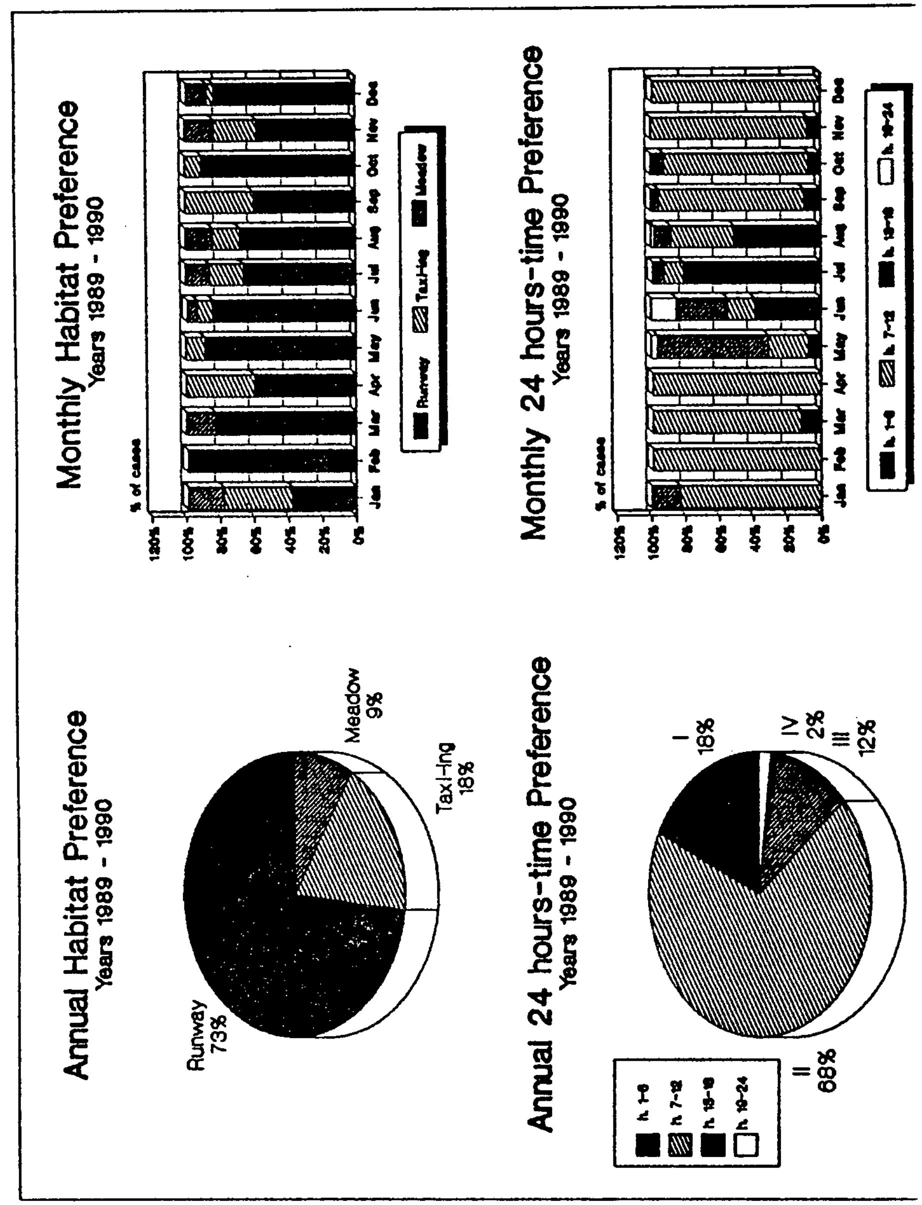
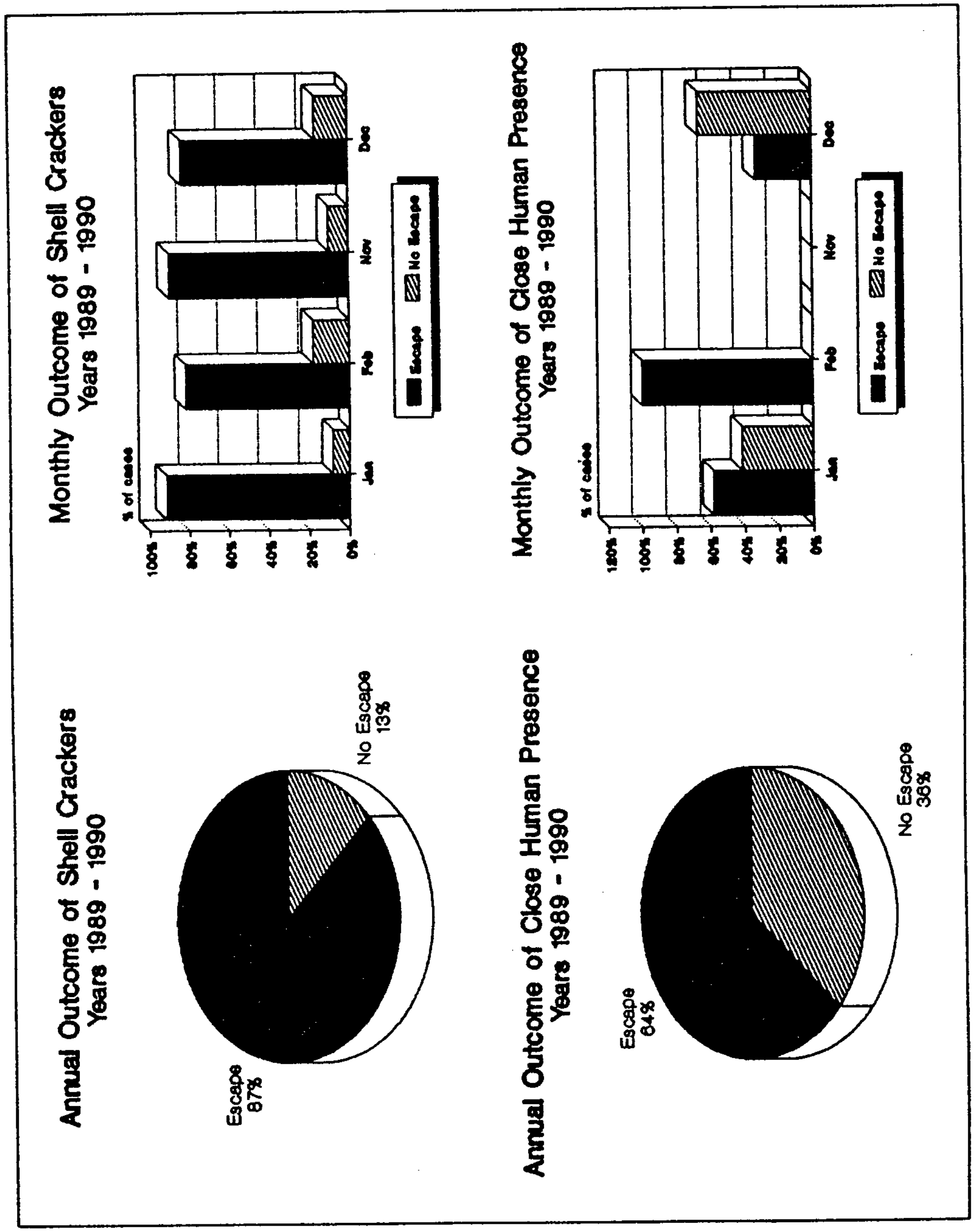


FIGURE 6. Outcome of two scaring measures in LAPWING.



RECENT PUBLICATIONS ON BIRDS AND AVIATION

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SUMMARY

The Paper contains brief details of publication on birds and aviation, which are known to the Author, produced since the previous BSCE Meeting (May 1990). Details of each publication ar its availability have been included. The Paper is divided into Research, Bird Control Measures Statistics and Engine Studies.

Issue 1 is being tabled at the Jerusalem BSCE Meeting. At the meeting it is expected that deta of further publications will become available, and these will be included such that an Issue 2 ca be included in the Proceedings.

1. BIRD RESEARCH

a. ***'Physiological Response of Birds to Approaching Aircraft'*** Ref: DOT/FAA/CT-91/14 Dated October 1991. The 91 page American Quarto-sized Report is available from Technical Information Service, Springfield, Virginia, 22161, USA.

SUMMARY

The laboratory study exposed birds to video scenes of aircraft during the take-off roll. Equipment to monitor the heart rate of the bird included a harness fitted with an Electrocardiogram (ECG) transmitter. The test birds were Laughing gulls *(Larus atricilla)* and Feral pigeons *(Columba livia domestica)* captured on or adjacent to Corpus Christi and San Antonio International Airports. Pigeons acclimated to airport sights and sounds were compared with pigeons not acclimated to airports. The video scenes of approaching aircraft caused heart rate increase in the unacclimated pigeons several seconds sooner than the acclimated birds, and the unacclimated pigeons were more responsive to the sound, as well as the sight, of approaching aircraft. Gulls and pigeons acclimated to airports used sight first, then sight-and-sound, and sound last as an indication of approaching aircraft during the video test.

The test birds equipped with ECG transmitters were positioned beside the active runway of San Antonio International Airport in individual cages.

The birds heart rate data were collected and stored on equipment in a mobile laboratory placed at the safety lines of a taxiway that crossed the active runway at the 4,000 ft mark. This distance from the start of the take-off roll gave the bird a view of aircraft during the rotation phases.

Aircraft tested included the 737-200, 737-300, 727-100, 727-200, DC-9, MD-80 and 767-100. The 24 test birds were exposed to over 100 aircraft departures during the test period from January through May 1990. The aircraft rotation was identified on the recorded data when the nose wheel left the ground during the take-off roll.

Statistical analysis of the recorded data was conducted and results from the analyses of variances were tested at the 5 percent level of significance. Birds exposed to the 767 wide-body aircraft experienced statistically higher maximum heart rates on the average than the other four (standard-body) aircraft. Gulls had a significantly higher average maximum heart rate than pigeons when tested at the aircraft rotation point response interval. The interval showed a higher percent change after take-off than before take-off. Gulls did not indicate by maximum heart rate response as much change as the Feral pigeons during the maximum sound response interval when the data was normalised by control tests.

Analysis of the closure rate of the aircraft to the test bird location indicated the bird response did not change significantly until the aircraft approach was within 1,000 feet of the bird. The aircraft velocity rate increase over this distance closes on the bird between 150 to 200 ft per second. The bird would have about 5 seconds to clear before impact with the aircraft. Early warning devices to alert the bird to approaching aircraft would need to be deployed prior to 10 seconds to allow the bird time to depart the runway area.

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b. ***'The Diagnostic and Phylogenetic Significance of Feather Structures'*** author Tim G Brom. The 279 page American Quarto-sized book is in English and describes the differences and similarities of the microscopic characteristics of bird feathers for identification purposes. The characteristics of the downy barbs of 350 mainly Palearctic birds are described and an identification key is presented. The Book is available from Instituut Voor Taxonomische Zoologie, University of Amsterdam, Mauritskade 61, Postbus 4766, 1009 AT Amsterdam, Netherlands.

2. BIRD CONTROL MEASURES

a. ***'Les Oiseaux des Aerodromes Francais, Prevantion du Peril avaiare'*** (The birds of French Aerodromes, prevention of Risk) by Jean-Luc Briot, Alain Eudot and Marc Laty published in French by Service Technique de La Navigation Aerienne, STNA/2NA 246 Rue Lecourbe, 75732 Paris CEDEX 15, France.

The 64 page A5 sized booklet describes each bird species with excellent colour illustrations. It includes the migration, behaviour on aerodromes, distribution across Europe at each time of year and most effective control method.

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b. ***'Bird Control on Aerodromes'***, CAP384 Published by UK Civil Aviation Authority, 37 Gratton Road, Cheltenham, Glos, England, GL50 2BN.

The 66 page A5 sized booklet published July 1990 covers bird identification and behaviour, habitat management, detection and dispersal methods and equipment. It contains colour illustrations and is intended to provide guidance to aerodrome operators on the measures which can be taken to produce effective bird control at an aerodrome.

3. STATISTICS

a. ***'Bird Strikes to Canadian Aircraft'*** 1984-88 Summary Report, Ref TP10574E. The 27 page American Quarto-sized data summary published during 1990 is available from Safety & Technical Services, Environmental Review Services Airports Group, Transport Canada, Ottawa, Ontario K1A 0N8, Canada.

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b. ***'Etude Statistique des Collisions Oiseaux - aeronefs survenues en France durant Les Annees 1988 and 1989'*** Ref 007/STNA/2S, by Monsieur J L Briot and Monsieur A Eudot. Published September 1990.

The 47 page A4 sized paper in French summarises and analyses the data for the two year period. There had been a 20% increase in number of bird strikes compared with the previous two year period, the strike rate was similar. There were 66 cases of damage. A Summary in English is included. The address is given in paragraph 2a.

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c. ***'Analysis of Bird strikes Reported by European Airlines 1981-1985'***, CAA Paper 92004 by J Thorpe. Available from Civil Aviation Authority, 37 Gratton Road, Cheltenham, Glos, England, GL50 2BN. The price is £3.55 inclusive of post and packing or £4.45 for overseas surface mail. The Paper was included in the proceedings of BSCE 20, Helsinki May 1990 as WP 28. The 31 page A4 sized paper summarises and analyses almost 7,500 strikes from 14 countries.

4. ENGINE STUDIES

a. ***'Study of the Engine Bird Ingestion Experience of the Boeing 737 Aircraft (October 1986-September 1989)'***. Ref DOT/FAA/CT-90/28 dated October 1991. The 179 page American Quarto-sized publication is available from National Technical Information Service, Springfield, Virginia 22161, USA.

SUMMARY

An investigation was initiated by the Federal Aviation Administration Technical Center in September 1986 to determine the number, weight, and species of birds which are ingested into medium and large inlet area turbofan engines during world-wide service operation and to determine what damage, if any, results. This report summarises the three years of Boeing 737 (B737) data that were collected to support this effort. The first year of data is published under report number DOT/FAA/CT-89/16 (1). The first and second years of data are summarised together and published under report number DOT/FAA/CT-89/29 (2).

A total of 8.91 million aircraft operations were flown by B737 commercial aircraft during the three year period of which Pratt and Whitney JT8D medium inlet area turbofan engines accounted for 71.8% and 28.2% were with CFM International CFM56 large inlet area turbofan engines.

During the three years of data collection, birds were ingested by one or both engines during 1,076 aircraft operation which yields a probability of aircraft ingestion of 1.21×10^{-4}. One or more birds were ingested into both engines of the aircraft during 31 of the 1,076 aircraft ingestion events. Thus, a total of 1,107 engine ingestion events were reported during the data collection period. There were 17.82 million engine operations during this period which yields a probability of engine ingestion of 6.21×10^{-5}. A conclusion of these data is that bird ingestion events are rare, but probable events.

When the species of the ingested bird was reliably identified, the most commonly ingested birds were from the order charadriiformes (shorebirds) - primarily gulls, lapwings, and plovers. The majority of ingested birds (155 of 167) weighed 1.13 kg or less. The bird weight distribution of ingested birds in the United States (284 gm) was smaller than the distribution of birds (397 gm) in foreign countries. Four birds larger than 1.86 kg were ingested abroad; whereas, only one bird larger than 1.86 kg was ingested in the United States. The bird ingestion rate within the United States was significantly lower than the foreign bird ingestion rate.

The majority of aircraft ingestion events (972 of 1,076) involved a single bird and a single engine on the aircraft. The remaining 104 aircraft ingestion events involved multiple birds and/or multiple engines.

Engine damage occurred in 45% of all engine ingestion events and there were 175 engine ingestions that resulted in engine damage classified as moderately severe or worse.

The majority (578 of 718) of aircraft ingestion events, for which the phase of flight was known, occurred within the airport environment during take-off and landing. The probability of engine damage is greater when the bird ingestion occurs during the take-off and climb phases of flight than when it occurs during approach and landing. Aircraft airspeed at or above 140 kts also increases the probability of engine damage.

It was determined that 3.8% of all engine bird ingestion events resulted in an engine failure. Five engine failures were caused by birds that weighed less than or equal to 450 gm. Engine failures are also more likely to occur when multiple birds are ingested into an engine.

The following summary shows the most pertinent statistics extracted from the three yeas of data for the B737 aircraft:

Probability of Ingestion Per Aircraft Operation	
World-wide	1.21×10^{-4}
United States	0.59×10^{-4}
Foreign	1.94×10^{-4}
Engines Experiencing Moderate/Severe Damage	175
Multiple Bird, Engine Ingestion Events	89
Dual Engine Aircraft Ingestion Events	31
Dual Engine, Multiple Bird Aircraft Ingestion Events	11
Single Engine, Multiple Bird Aircraft Ingestion Events	73
Aircraft Ingestion Events By Phase-of-Flight	
Take-off and Climb Phase-of-Flight	63.8%
Approach and Landing	33.4%

b. ***'Study of Bird Ingestions Into Small Inlet Area Aircraft Turbine Engines (May 1987 to April 1989)'***. Ref DOT/FAA/CT-90/13 dated December 1990. The 78 page report is available from address in paragraph 4a.

SUMMARY

An investigation was initiated by the Federal Aviation Administration (FAA) Technical Center in May 1987 to determine the numbers, weight, and species of birds which are ingested into small inlet area turbofan and turboprop engines during world-wide service operation and to determine what damage, if any, results. Small inlet area engines are defined as those engines having an inlet area up to approximately 1,400 square inches. This report presents an analysis of the two years of data. The purpose of the analysis is to assist the FAA in evaluating certification test requirements for such engines. In particular, this report presents information concerning ingestion events as related to time of day, phase of flight, month, location and bird species and weight.

Throughout the world during that time there were approximately 16 million operations by the engines included in the data (ALF502, TFE731, TPE331 and JT15D). This figure includes 24 months of operations for the first 3 engines and 12 months of operation for the fourth. A total of 210 engine ingestion events were reported during this period. The probability of an engine ingestion event occurring is 1.3×10^{-5} per operation. Thus, the ingestion of a bird is a rare but not impossible occurrence.

Within the United States, the most frequently ingested bird weight is 113 gm, while outside the United States, the most frequently ingested bird weight is 223 gm.

It was found that ingestions occurred more frequently in the daytime than at night. More than likely this is the result of 2 factors: fewer aircraft flight at night and more birds flying in the daytime.

It was determined that the engine ingestions could be described adequately by a Poisson distribution. This made is possible to test hypotheses about the relationship between engine size and ingestion rate. The data are consistent with the hypothesis that ingestion rates are directly related to engine cross section area. It was determined that the ingestion experience of the turboprop engine was different from that of the turbofan engines, but the reasons for this difference could not be determined.

It was observed that the same number of engine ingestion events occurred in the combined take-off/climb phases of flight as in the combined approach/landing phases of flight. The ration of landing events to approach was close to one (55:45), whereas the ratio of take-off events to climb events exceeded 10 (91:9). Less than 5% of all ingestion events occurred during taxi or at cruise altitude.

Engine damage occurred in 50% of all engine ingestion events, and it was not the case that there was a threshold bird weight such that smaller birds did no damage and larger birds always caused damage. Instead, the probability of damage increased with bird weight. However, in some events small birds caused damage, while in other events larger birds caused no damage at all. Probability of damage versus bird weight curves were computed from the data. Also, the probability of engine damage is greater when the bird ingestion occurs during the take-off and climb phases of flight than when it occurs during approach and landing. Aircraft airspeed at or above 140 knots also increases the probability of engine damage.

It was determined that 5% of all engine bird ingestion events resulted in an engine failure. Four engine failures were caused by birds that weighed more than 1.86 kg and 2 were caused by birds that weighed less than 225 gm. Engine failures are also more likely to occur when multiple birds are ingested into an engine.

Probability of Ingestion per Engine Operation	
World-wide (all engine types)	1.3×10^{-5}
United States (JT15D engine excluded)	1.04×10^{-5}
Foreign (JT15D engine excluded)	1.922×10^{-5}
Most Commonly Ingested Bird	
United States	Dove
Foreign	Lapwing
Engines Experiencing Moderate/Severe Damage	
Turbofans	41
Turboprops	2

5. GENERAL

'Vogel und Luftverkehr' All aspects of bird strike problem. Two Journals per year. In German with English Summary. Approximately 60 pages A5 size. 15 DM per annum from Bird Strike Committee Germany, Frŏschenpuhl 6, D-5580 Traben-Trarbach, Germany.

BSCE 21/WP 34
Jerusalem, 23-28 May 1992

AN ANNOTATED BIBLIOGRAPHY OF BIRD HAZARDS TO AIRCRAFT

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WPAFB, OH 45433 USA
and
A.J. Poulis
HQ AFCESA/TIC
Tyndall AFB FL 32403 USA

ABSTRACT

A centralized information bibliographic source is useful to bring together studies that can be reviewed and serve as a starting point for additional research. The working papers of the Bird Strike Committee Europe, along with articles published in scientific journals and proceedings from workshops sponsored by other state or international agencies, form the majority of what is known about bird hazards to aircraft and what can be done to reduce bird-aircraft interactions. A project to produce an annotated bibliography of bird hazard-related research is underway in cooperation with the U.S. Air Force Civil Engineering Agency's Technical Information Center. Compiling this information in an easily accessible document would assist bird hazard researchers, worldwide. A magnetic format for the bibliography is planned that will facilitate keyword searches and will provide a comprehensive summary of research. The BSCE is solicited to provide input and expertise during the development of the bibliography.

Keywords: bibliography; bird hazards; annotated; database

AN ANNOTATED BIBLIOGRAPHY FOR BIRD HAZARDS TO AIRCRAFT

1.0 PURPOSE

The purpose of this paper is to suggest a format and initial operational strategy for the preparation of an annotated bibliography for bird hazards to aircraft (termed here as ABBHA).

2.0 INTRODUCTION

At the 20th Congressus Internationalis Ornithologicus held in Christchurch, New Zealand (2-9 December, 1990), members of the Standing Committee on Applied Ornithology (SCAO) recognized the need to provide ornithological researchers access to existing literature on bird hazards to aircraft. Subsequent discussions with the SCAO chairman, Dr. Hans Blokpoel, affirmed that an annotated bibliography of birdstrike-related research would help lay the foundation for expanding the international research on this subject. An annotated bibliography would provide a readily available list of articles or books that deal with bird hazards to aircraft and an explanation of the information contained therein.

2.1 Background

It is often time-consuming and many times difficult to locate certain studies concerning bird hazards to aircraft. There are many excellent sources of information concerning bird hazards. Through its proceedings, working group reports and other documents, the Bird Strike Committee Europe perhaps is the premier international source of information on bird hazards to civil and military aircraft (See BSCE 19/WP3). Workshops conducted by the International Civil Aviation Organization as well as state-sponsored conferences have provided valuable information exchange for a wide range of bird hazard research topics. However, there remains a need for a central clearinghouse for bird hazard information that can be accessed by researchers worldwide.

2.2 BASH Team Bibliographic Database

The U.S. Air Force Bird-Aircraft Strike Hazard (BASH) Team maintains an extensive library on bird as well as other animal hazards to aircraft. The BASH Team uses the library resources of the USAF Civil Engineering Support Agency's Technical Information Center (HQ AFCESA/TIC) to locate documents to support their research and analysis activities. The AFCESA/TIC conducts bibliographic searches through a network of databases to provide their customers with the needed information. AFCESA/TIC is categorizing the BASH Team's reference documents and entering the information into a database easily accessible by other researchers. When complete, the AFCESA/TIC will maintain a large collection of BASH-related material for access by all researchers. Documents maintained at other information centers will not be copied and distributed by the AFCESA/TIC. The AFCESA/TIC can provide information on where specific documents or microfiche can be obtained. However, if difficulties are encountered in acquiring the full text from either the source or through your local corporate or university libraries, AFCESA/TIC will assist.

3.0 BIBLIOGRAPHIC SOURCES

The AFCESA/TIC searched several existing biological and engineering databases for documents relating to bird hazards to aircraft:

(1) Defense Technical Information Center (DTIC);
(2) Zoological Record (ZoolRcd);
(3) BIOSIS Previews (BIOSIS);
(4) Dissertation Abstracts (DissAbs);
(5) National Technical Information Service (NTIS);
(6) Transportation Research Information Service (TRIS);
(7) Aerospace Database (Aerospace);
(8) Engineering Index (EI);
(9) NASA/RECON; and,
(10) (US) Government Printing Office (GPO) Reference File.

Selection of these reference sources was based on the relevancy to the subject of bird hazards rather than the authoritative nature of the references themselves. No attempt was made to judge the value of the material such as quality of reported research.

3.1 Bird Hazard Citations

Table 1 provides a breakdown of bird hazard citations for each reference source. The information was screened to eliminate obvious non-relevant material and duplications. Most of the citations listed were either titles only or short bibliographic records.

TABLE 1

Source	Number of cites[1]	Bibliographic References
DTIC	273	2
ZoolRcd	120	None
BIOSIS	9	None
DissAbs	2	None
NTIS	234	1
TRIS	75	3
Aerospace	188	1
EI	67	None
NASA/RECON	53	1
GPO	2	None
Total	1023	8

[1]May include replications from other sources

Eight bibliographic citations were located; five are presented in Appendix A. On request, all bibliographic databases searched could provide a document containing the retrieved information; some could provide it in magnetic format. Several sources charge for preparing bibliographic searches while others provide the information as a subscription service.

Many do not have abstracts. Some studies presented at the BSCE and also published in other scientific journals. Of all considered, the DTIC provided the most complete search of bird hazard research.

4.0 ISSUES

Development of an annotated bibliography for bird hazards to aircraft (ABBHA) will require consolidation of a diverse asssortment of literature from many worldwide sources. ABBHA must

be responsive to the wide assortment of research needs for bird management, bird avoidance and bird tolerance engineering. However, the ABBHA must be limited to those studies directly related to bird hazards to aircraft or it will lose its research relevance. The ABBHA can provide ornithologists and engineers, alike, a ready reference document to help locate studies and plan research.

4.1 Availability
To comply with the purpose of the ABBHA, the database must be reasonably available to all researchers, worldwide. Though a hard-copy (paper) document is the usual method of distribution, a magnetic format would probably offer the user the most flexibility for searching the ABBHA. The magnetic format would also allow easy updates of the citations and would enhance distribution to a wide audience. Microfiche copies might be available for some articles.

4.2 Accessibility
ABBHA hardware and software requirements must be affordable for the user as well as the host. Relatively modest computer hardware (usually IBM-PC/XT/AT or compatible) will run most bibliographic software. Many computer programs are available for development of the ABBHA but the costs must be kept as low as possible to allow access by researchers with limited computer resources. Some bibliographic search/retrieval software is available from the NTIS for a nominal fee while others are more expensive (see "REFEREE" information at Appendix B). The authors will review several different software packages to suggest alternatives to optimize use and reduce costs.

4.3 Maintainability
The ABBHA database will be updated annually with new articles. The development and maintenance of the ABBHA promises to be an involved and possibly costly effort to access existing bibliographic information and to augment the ABBHA with missing literature, such as studies reported in the BSCE proceedings which are not currently in a database. Existing bibliographic sources will be used to locate copies of studies. Articles from the BSCE and other documents not available from bibiographic sources will be entered into the AFCESA/TIC database. (It would be helpful if the AFCESA/TIC could be provided copies of the early (BSCE 1-10) proceedings.) If appropriate, the information may be exported into a national database; e.g., DTIC. However, any material entered into a national database must comply with database rules and idiosyncrasies.

4.4 Capability
The AFCESA/TIC will soon include an Environmental Quality Information Analysis Center (EQIAC). When the EQIAC is fully operational it will be able to provide a technical analysis of available information on bird hazards for USAF customers as well as many other environmental areas (see Appendix C). The EQIAC will have the capability to synthesize results of research and other information collected through its literature searches. (Please contact Mr. Poulis for additional information or questions on the EQIAC). Any documents included into a national database must comply with existing distribution regulations.

5.0 RECOMMENDED BSCE ACTIONS
The BSCE could provide the oversight of the ABBHA development. It is suggested here that the BSCE establish a "Bibliography Working Group" to provide expert advice and to openly discuss issues associated with the transition of the ABBHA to the research community. This working group should review progress and ensure that the ABBHA is useful and meets the user requirements.

The BSCE could provide an excellent platform for the testing of the ABBHA, whatever final form it takes. In addition, a BSCE working group could help address the following issues during the development of ABBHA:

(1) database fields;
(2) standardized search descriptors (proposed in Appendix D);
(3) format and software;
(4) updates and other maintenance.

6:NTIS 64-92/9203B2
(COPR. 1992 NTIS)

:09131/5
›9131 NTIS Accession Number: NTIS/PS-76/0538/9
Bird Strikes and Aviation Safety (A Bibliography with Abstracts)
(Rept. for 1964-Jun 76)
Habercom, Jr, Guy E.
National Technical Information Service, Springfield, Va.
Corp. Source Codes: 391812
Jul 76 54p
Document Type: Bibliography
Journal Announcement: GRAI7617
NTIS Prices: PC N01/MF N01
Hazards to aircraft created by engine ingestion or airplane interception
birds are investigated in these Government-sponsored research reports.
rd damage assessment, structural strengthening, windshield design, and
rd tracking and dispersal methods are studied. (Contains 49 abstracts)
Descriptors: *Bibliographies; *Aviation safety; *Ingestion(Engines);
rcraft windows; Impact shock; Impact strength; Birds; Collision research;
dar tracking; Migrations; Abstracts
Identifiers: *Bird strikes; NTISNTIS
Section Headings: 1B (Aeronautics--Aeronautics); 85D* (Transportation--Tr
sportation Safety); 85A (Transportation--Air Transportation); 51B
.eronautics and Aerodynamics--Aeronautics)F

le 63:TRIS 70-91/NOV

8789 DA
BIRD STRIKES AND AVIATION SAFETY. 1964-JUNE, 1980 (CITATIONS FROM THE
IS DATA BASE)
Habercom, GEJ
National Technical Information Service, Springfield, VA.
Jul 1980 117p
SUBFILE: NTIS
AVAILABLE FROM: National Technical Information Service 5285 Port Royal
ad Springfield Virginia 22161
Hazards to aircraft created by engine ingestion or airplane interception
birds are investigated in these Government-sponsored research reports.
rd damage assessment, structural strengthening, windshield design, and
rd tracking and dispersal methods are studied. (This updated bibliography
ntains 107 citations, 17 of which are new entries to the previous
ition.)
DESCRIPTORS: ABSTRACTS; AIRCRAFT WINDOWS; AVIATION SAFETY; BIBLIOGRAPHIES
BIRD STRIKES; BIRDS; COLLISION RESEARCH; IMPACT SHOCK; IMPACT STRENGTH;
GESTION ENGINES; MIGRATIONS; RADAR TRACKING

4571 DA
BIRD STRIKE HAZARDS: A BIBLIOGRAPHY, 1971 - 1976
Murthy, HSS
National Aeronautical Laboratory; Information Centre for Aeronautics;
ngalore; India
Jun 1977 22 pp
REPORT NO: NAL-BIBL-SER-77
SUBFILE: NTIS; ATRIS
AVAILABLE FROM: National Technical Information Service 5285 Port Royal
ad Springfield Virginia 22161
A comprehensive collection of literature on aircraft bird strike hazards

presented. The entries are arranged into six groups: (1) literature
rvey; (2) bird ingestion; (3) environmental control; (4) laser
chniques; (5) radar techniques; and (6) structural design. An author
dex is provided.
DESCRIPTORS: AIRCRAFT ACCIDENTS; AIRCRAFT SAFETY; BIBLIOGRAPHIES; BIRD
RCRAFT COLLISIONS; BIRD STRIKES; ENVIRONMENTAL CONTROL; INDIA; LASERS;
DAR; SAFETY; SAFETY MANAGEMENT; STRUCTURAL DESIGN

5961 DA
A REVIEW OF PUBLICATIONS ON THE BIRD/AIRCRAFT STRIKE HAZARD
Moorehead, AS; McCracken, PR
Air Force Civil Engineering Center; Tyndall AFB; Florida
Jul 1976 Final Rpt. 26 pp
REPORT NO: AFCEC-TR-76-21
SUBFILE: NTIS; ATRIS
AVAILABLE FROM: National Technical Information Service 5285 Port Royal
ad Springfield Virginia 22161
The annual cost to the United States Air Force (USAF) to replace or
pair aircraft damaged by bird/aircraft collisions has led to an intensive
udy of the problems associated with birds on airfields and in the enroute
vironment. Since 1969 an active program has been in effect, first at the
r Force Weapons Laboratory (AFWL) at Kirtland Air Force Base, New Mexico,
d in 1975 at the Air Force Civil Engineering Center (AFCEC), Tyndall Air
rce Base, Florida. This report reviews those Technical Notes (TNs) and
chnical Reports (TRs) that have been published as a result of the program
fort. (Author)
DESCRIPTORS: AIRCRAFT COLLISIONS; AIRCRAFT MAINTENANCE; AIRCRAFT SAFETY;
RPORTS; AVIATION ACCIDENTS; AVIATION SAFETY; BIRD STRIKES; COST ANALYSIS;
STS; DAMAGE ASSESSMENT; ENROUTE; HAZARDS; REVIEWS; SAFETY

le 108:AEROSPACE 62-92/ISS04
(COPR. AIAA 1992)

Set Items Description
--- ----- -----------

ɔ5105 N68-22034
Bird hazards to aircraft - A literature survey, January 1947 - September
57 (Literature survey on bird hazards to aircraft and attempts to
sperse birds from airfields)
WIJNEN, J.
Technisch Documentatie en Informatie Centrum voor de Krijgsmacht, The
gue (Netherlands).
Publication Date: Oct. 1967 55P.
Report No.: TDCK-49208
Language: MULTIPLE; IN FRENCH, ENGLISH, GERMAN, AND DUTCH
Country of Origin: Netherlands Country of Publication: Netherlands
Document Type: REPORT
Documents available from AIAA Technical Library
Other Availability: NTIS
Journal Announcement: STAR6812
Source of Abstract/Subfile: NASA STIF
Descriptors: *AIRCRAFT HAZARDS; *BIBLIOGRAPHIES; *BIRDS; *FLIGHT HAZARDS
ABSTRACTS; AIRCRAFT SAFETY; IMPACT DAMAGE; INGESTION (ENGINES);
TERATURE
Subject Classification: 6502 Aircraft (1965-74)

APPENDIX B

Computer Product Information Sheet

NTIS Federal Computer Products Center
UNITED STATES DEPARTMENT OF COMMERCE
National Technical Information Service
5285 Port Royal Road, Springfield, VA 22161

TO ORDER: **Phone: (703) 487-4650** **FAX: 703-321-8547** **Telex: 64617**
(Also available on a Rush basis for an added fee)

Model-Simulation

Title:
REFEREE: Bibliographic Database Manager Version 4.2 (for microcomputers)

Source: Environmental Protection Agency
NTIS Order Number: **PB91-509794** Product Type: **Software-Diskette**
Date: 8/4/87
Price Code: D02 U.S., Canada, & Mexico: $80.00, all other addresses: $160.00

(Price includes documentation, add $3 to each order for handling)

Summary:
REFEREE is a general-purpose bibliographic database management program for IBM-compatible microcomputers. The program is ideal for maintenance of large, master databases from which lists of citations on desired topics frequently must be drawn.
IREFEREE databases exist as proprietary-format disk files. The program allows entry of information manually (from the keyboard) and automatically (bulk transfers from dBASE.DBF files). Each record in a REFEREE database contains 9 fields. Seven of the fields are variable-length free-text fields that have essentially no format requirements; each can extend to nearly 6000 characters when necessary (disk space is allocated on a field-by-field record-by-record basis). All fields can be renamed to suit the user's needs. Up to 1 million records theoretically can be stored in a single REFEREE database: the actual maximum number depends on the amount of disk space available. Stored records can be viewed, modified, searched, sorted, printed, moved between REFEREE databases, and exported to DBASE .DBF files. By default, records are displayed and printed in a format that includes the names and contents of all 9 fields; the user may define custom formats that involve a different selection or order of fields, different line spacing or indentation, or boilerplate text.

The software is on two 5 1/4 inch diskettes, 360K double density. File format: Clipper Microsoft C5.1 8086 as. The diskette(s) are in ASCII format. Documentation included; may be ordered separately as PB91-228791.

System: IBM-PC/XT/AT or compatible; MS-DOS 2.0 + operating system, 400K. Memory requirement - 490K RAM, 400K free disk space for software; data requires additional. Supersedes PB88-200779.

HQ AFCESA/TIC (FL7050)
Technical Information Center
Bldg 1120/Stop 21
Tyndall AFB FL 32403-6001

Refund Policy: **NTIS does not permit return of items for credit or refund. A replacement will be provided if an error is made in filling your order, if the item was received in damaged condition, or if the item is defective.**

APPENDIX C

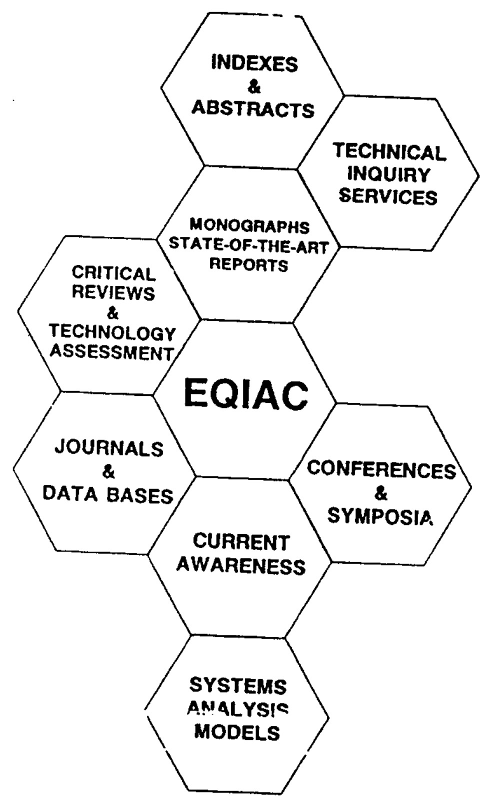
AIR FORCE ENGINEERING AND SERVICES CENTER

TECHDATA

ENIRONMENTAL QUALITY INFORMATION ANALYSIS CENTER (EQIAC)

RDX-91-1

July 1991



SYNOPSIS:
AFESC's Engineering and Services Laboratory has established the Environmental Quality Information Analysis Center (EQIAC) to gather,review, analyze and disseminate information in the areas of site restoration (SR), pollution prevention (PP), hazardous waste minimization (HWM), and environmental compliance (EC). This fulfills requirements for environmental data analysis and information transfer, two major categories of concern in the Environmental Quality Strategic Research and Development Program.

The most pressing problems confronting those involved in the research and application of new technologies in these critical areas have been the lack of an information focal point and the lack of a capability to obtain scientific/technical and cost-benefit analyses of (new) information in the SR, PP, HWM, and EC subareas. These analyses, as well as assessments of the state of the art and of current scientific developments and trends require capabilities not present in existing environmental information repositories; the combined skills of information specialists, researchers, field practitioners, and others in the federal, state, academic, and industrial community. Such services are essential to cost-effective and proactive environmental quality research, development and acquisition programs. The EQIAC was formed to meet these requirements in an economical, efficient, and unbiased manner.

The EQIAC provides technical,

E&S TechData sheets are products of HQ AFESC/RDXI, Tyndall AFB, Fla., 32403-6001.

programmatic, and systems, and benefit analyses of the latest scientific developments in target EQ areas. It can respond to queries and referrals by accessing, reviewing and evaluating the literature, developing annotated bibliographies, and by enlisting the aid of a diversity of specialists to determine the focus of present and future activities and assess trends.

The EQIAC has ready access to thousands of commercial and government databases, as well as those of colleges and universities. Its own database resources include computerized bibliographic information on thousands of documents from DOD, other government agencies, industry and academic institutions. Hardcopy resources include books, technical reports, conference and symposium proceedings, standards and specifications, patents, and unpublished papers on environmental quality topics such as hazardous waste disposal and treatment technologies, site restoration, environmental pollution control, and environmental compliance.

PRODUCTS AND SERVICES:
EQIAC areas of emphasis are to: (1) review, analyze, and summarize data on EQ topics and issues; (2) provide programmatic decision tools to researchers and scientific managers; (3) identify and begin addressing voids in existing environmental information resources; and (4) disseminate information to users through periodic updates, bibliographies, state-of-the-art reviews, handbooks, and special reports. As an information focal point, the EQIAC will provide referrals to those agencies best suited to meet the users' specific needs. This will further the full utilization of the expertise in place at other organizations.

The EQIAC will also assist its users with the management and planning of EQ conferences and seminars and can assist with the development of specialized handbooks and audiovisual aids. The results of conferences and seminars will be published and shared with the worldwide scientific and engineering community.

BENEFIT:
The EQIAC will facilitate more cost-effective site restoration pollution prevention, hazardous waste minimization, and environmental compliance efforts by providing EQ decision-makers, program managers, and researchers with timely access to the environmentally related research and technology information needed to accomplish their duties.

AVAILABILITY:
E'QIAC's products and services are available to DOD environmental organizations, laboratories, managers and planners, DOE, EPA and other federal, state and local agencies, academia, and the private sector.

USER CONTACT:
Mr. Andrew Poulis
HA AFESC/TIC
Tyndall AFB FL 32403
DSN 523-6258
Comm (904)283-6258

APPENDIX D

Proposed Search Descriptors for ABBHA

Bird Attractants
- *Food*
- *Vegetation*
- *Water*
- *Garbage*
- *Weather*

Bird Avoidance
- *Airfield Environs*
- *Inflight Manuevering*
- *Preflight Planning*
- *Modelling Bird Risk*

Bird Control Measures-Airfield
- *Bioacoustics*
- *Depredation*
  - *Falconry*
  - *Shooting*
  - *Chemical controls*
  - *Trapping*
  - *Predators*
- *Effigies*
- *Electronics*
- *Habitat*
- *Lights*
- *Mechanical*
- *Pyrotechnics*
- *Visual*

Bird Control Measures-Facilities
- *Bioacoustics*
- *Building Design*
- *Depredation*
  - *Falconry*
  - *Shooting*
  - *Chemical controls*
  - *Trapping*
  - *Predators*
- *Effigies*
- *Electronics*
- *Lights*
- *Mechanical*
- *Visual*

Bird Populations
- *Migratory*
- *Resident*
- *Behavior*
- *Marking*
- *Vectors of disease*

Bird Detection
- *Radar*
- *Visual*
- *Sound*
- *Electronic*

Bird Physiology
- *Flight*
- *Fright*
- *Sensory*
  - *Auditory*
  - *Tactile*
  - *Visual*

Bird Hazard Management
- *Plans*
- *Reporting*
- *Statistics*

Legal Issues
- *Conservation*
- *Protection*
- *Refuges*
- *Hunting*
- *Siting-Airports*
- *Siting-Attractants*
  - *Landfills (Rubbish Tips)*
  - *Offal Pits (Abbatoirs)*
  - *Wastewater Treatment*

BSCE 21 WP 35
JERUSALEM, MARCH 1992

BIRD STRIKES AT BEN-GURION AIRPORT, ISRAEL 1982-1991

JERRY YASHON and EYAL SHY

Bird Strike Prevention Unit, Nature Reserves Authority,
Ben-Gurion Airport, P.O.B .126, Israel 70100

Introduction

Ben Gurion International Airport resides in an area of intensive agricultural activity. As such it is a contiguous part of the regional ecosystem in which it is located. Indeed, within the boundaries of the airport itself there is ongoing agricultural activity in land adjacent to the runways. However, as distinct from the activity outside the airport boundaries, the type of agriculture allowed within the airport perimeter is subject to the prior consent of the Airport Authority which has veto power over any activity that could conceivably have adverse effects on aircraft safety either directly or indirectly.

As a consequence of being located within an agricultural environment the airport is subject to bird activity congruent with this type of environment. In addition, the close proximity to the airport of a large municipal refuse dump serves as a powerful attractant to birds, especially during the winter months when migrating birds such as gulls and terns are resident in Israel.

In order to cope with the threat from bird activity to aviation safety the Airport Authority maintains a Bird Strike Prevention Unit staffed by the Nature Reserves Authority. This arrangement allows the unit flexibility and the authority to take extraordinary measures regarding animal activity, when deemed necessary, which is not permitted to any other body outside of the Nature Reserves Authority. The priority is to ensure that aviation safety is maintained at the highest possible level with a minimal impact upon the local environmental balance of nature.

Bird Strike Prevention Unit

The Bird Strike Prevention Unit operates from first light to last light throughout the entire week with the exception of Saturday. The runways are patrolled at first light to ensure they are clear of any activity which may threaten aviation safety. Synthetic and recorded distress signals emanating from the patrol vehicle are used to encourage any birds in the area to relocate to less hazardous surroundings. Cracker shells are used to distance birds seen in the air. Routine patrols are carried out during the day to monitor agricultural areas

near the runways and locate any potential problems before they become a threat. Gas cannons operate at sensitive points near the runways and when necessary additional cannon are set up where increased bird activity has been noted. Problem populations are culled on a regular basis. During winter operations the unit also employs specially adapted drone aircraft outside the airport to break up and distance large flocks of birds near the refuse dump which may endanger aircraft approaching the airport. In this manner the Bird Strike Prevention Unit strives to provide the most effective on site and peripheral bird strike deterrent action given the resources available to it.

Agriculture at Ben Gurion International Airport

As previously noted there is ongoing agricultural activity within the operational area of the airport. The overriding concern is to ensure that all land under Airport Authority control is managed in such a way that bird activity will not be attracted to the airport. Two nearby agricultural communes (kibbutzim) are allowed the use of the available arable land for raising crops. However, the Airport Authority reserves the right to determine which crops are allowed, with a balance being struck between the farmers' need for viable crops which can be marketed and the airport priority that they not attract birds. Accordingly, no seed producing crops are allowed unless they are raised for cattle feed and harvested before the seeds become edible. These include wheat, corn, pensilaria and vetch. Cotton is favored by the airport, however, the large amount of water needed with its related high cost in Israel make it less profitable to raise. Chickpeas have recently been introduced on a trial basis with encouraging results. Land that is not utilized for raising crops is maintained by the engineering and gardening departments who are responsible for containing the spread on any undesirable plant growth which could attract birds.

Despite the careful selection of crops allowed at the airport there always remains some attendant bird activity. Flocks of pigeons search for seeds during planting and immediately afterwards. Cattle egrets follow tractors plowing the fields alert for anything edible that may be exposed. Predators are evident hunting for prey above the fields. There also remains bird activity just outside of the airport perimeter in fields adjacent to the airport that are not limited to specific crops and often do attract birds. All this activity ensures that even in the best of circumstances there remains plenty of work for the Bird Strike Prevention Unit.

Environmental Factors

Israel is a small country, but has a variety of climates supporting different ecosystems. This ranges from the lush Galilee and Golan in the north to the arid Negev in the south and from the coastal plain along the Mediterranean Sea to the rolling hills around Jerusalem and down to the lowest point on earth, the Dead Sea. These varied habitats support different resident bird species. Also, because of its geographical location Israel serves as a bridge over which pass great migrations of birds during the autumn from Europe and Asia south to their winter quarters in Africa and back north to their breeding grounds during the spring. During their passage they stop to feed and rest. However, not all of the birds complete the journey and some choose to winter in Israel. As a result of all this bird activity aircraft are exposed to the threat of bird strike from various sources which change in prevalence depending upon the time of the year.

Bird populations resident in and around the airport throughout the year include the chukar partridge, spur-winged plover, cattle egret, hooded crow, lark, pigeon and dove. During the summer months greater activity is evidenced by the stone curlew, swift and swallow. Resident raptors include the kestrel and barn owl. The winter is characterized by the appearance of ducks, coots, lapwings and a massive increase in various gulls, especially the black headed gull. Raptors seen near the airport during the winter include the black kite and buzzard who often hunt in the fields in and around the airport. During the spring and autumn the great migrations which pass over Israel proximate to the airport include storks, pelicans and various raptors. The end result of all this bird activity in and around Ben Gurion International Airport can be seen in the bird strike data which follow.

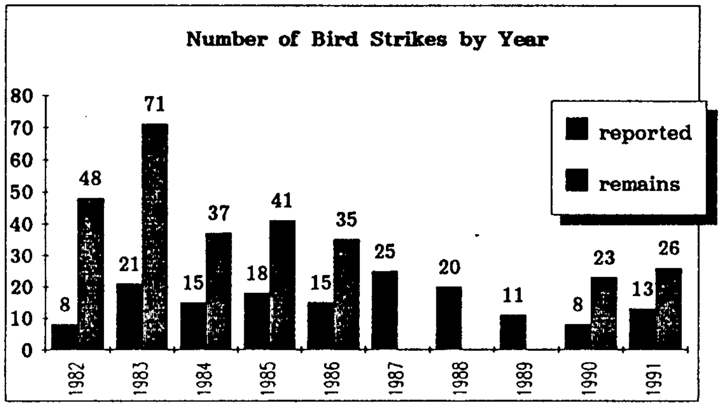
RESULTS

The results of the last five years have been added to the data presented at the Madrid BSCE meeting to show a decade of bird strikes at Ben-Gurion International Airport.

Figure 1 shows the number of bird strikes over the last ten years. During the last five years (1987-1991), 77 reported strikes occurred at Ben-Gurion International Airport, which incidentally is exactly the same number of strikes that had been reported in the previous five years (1982-1986). This in spite of the fact that the total number of strikes changes considerably from year to year. According to information on the number of civilian aircraft movements at the airport, the average number of strikes is estimated to be one per 2500

aircraft movements. The number of incidents in which bird remains were found during 1987-1989 were not included in this figure because not all of them were recorded. During all the years for which information has been collected, the number of cases in which bird remains had been found is much larger than the number of reported strikes.

Figure 1

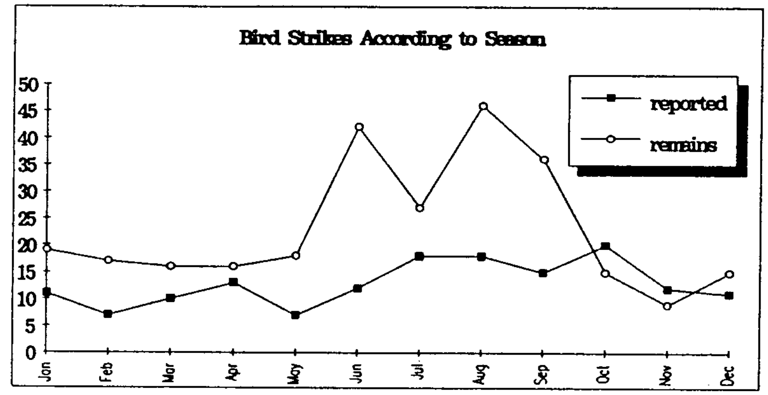


Seasonal changes in bird strikes

The changes in the number of bird strikes during the year for the last decade is shown in Figure 2.

The greatest number of bird strikes occur during the summer and early autumn. Smaller peaks of strikes occur during spring and October. The smaller peaks may be explained by the heavy migration during this period. However, the largest amount of strikes during the summer may be explained by the type of species that collide with airplanes and by their species specific behavior. Also the greater number of aircraft movements during this period is a probable factor.

Figure 2



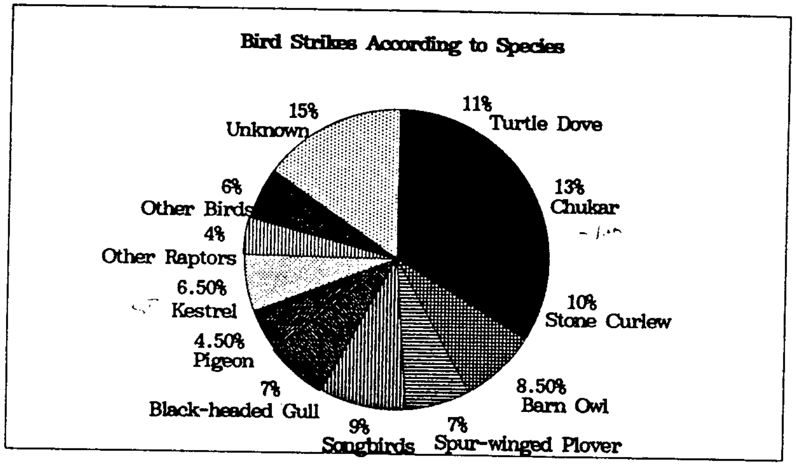
The bird species involved in collisions

Although hundreds of species of birds stay in Israel for varying periods throughout the year, only about 40 of them have been known to collide with aircraft and of those, only ten are involved in about 75% of the strikes. The pie chart in Figure 3 describes the distribution of bird strikes among these species.

Chukars, stone curlews, spur-winged plovers, barn owls, and kestrels are residents in Israel and the first three species tend to breed near the runways, or in the fields near them. Turtle doves migrate in large number during the autumn. Black-headed gulls stay by the large refuse dump near the airport throughout the winter. Thousands of them arrive at the dump early in the season, but by employing the techniques previously described in the winter operations, their number is significantly reduced. This may explain the fact that less than 7% of the strikes involve this species.

During the last decade, stone curlews were involved in 40 collisions with airplanes. However, only in one case were bird remains found on the aircraft, in spite of the fact that this species which is mainly active at night, is often found near the runways. This may be attributed to its behavior which tends to remain on or near ground level.

Figure 3



Altitude and flight stage during bird strikes

Figures 4 and 5 show the distribution of bird strikes according to altitude (in feet) and flight stage. These two variables are related. It is clear from the figures that most of the strikes occur up to 100 feet, during take-off and landing. This emphasizes the importance of the measures taken to control bird strikes on the ground near the runways.

The number of bird strikes during take-off is considerably larger than that during the landing roll. This may be explained by the longer "warning" time to the birds by the oncoming airplane (above them) during landing than during take-off. Decreased warning time may also be a factor contributing to the larger number of bird strikes on approach, when engine power along with its associated noise is greatly reduced, as compared to climbing when full power is used.

Distribution of bird strikes during the day

It is clear that the majority of them (about 75%) occurred during the daylight. This is not surprising as most of the bird and aircraft activity takes place during this period.

Figure 4

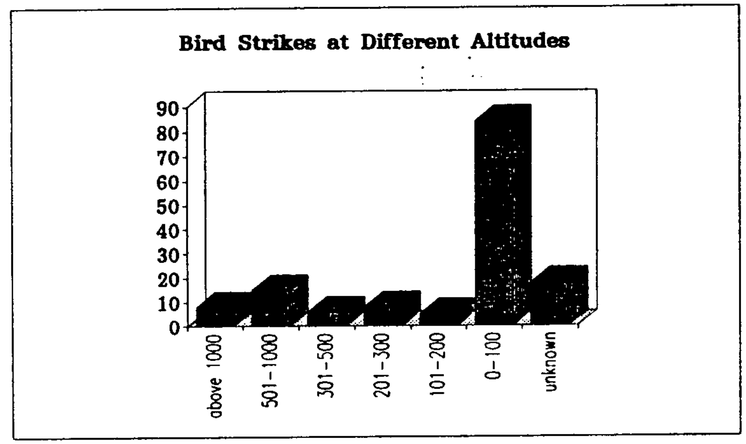
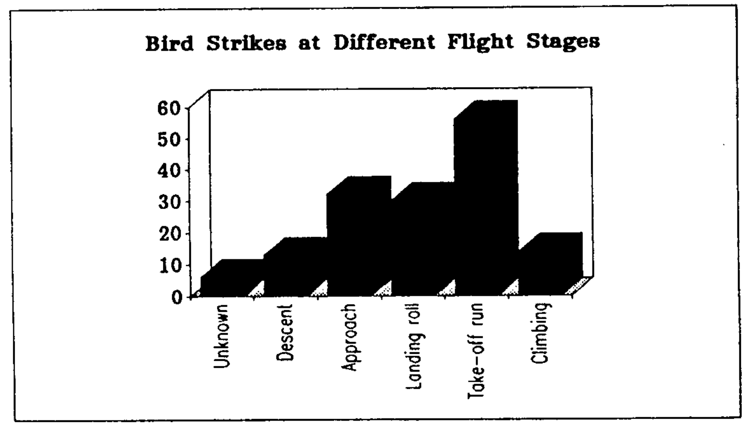


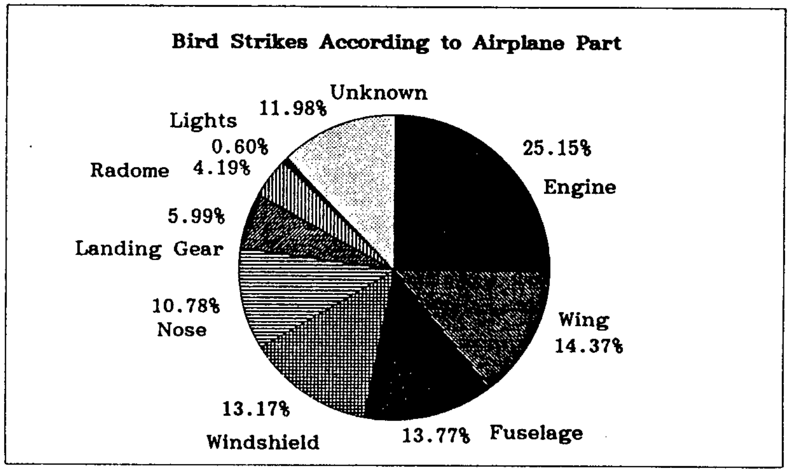
Figure 5



The damage caused by bird strikes to airplanes

The distribution of strikes according to airplane parts is shown in Figure 6. As can be seen in the chart the engine has the greatest potential for bird strikes.

Figure 6



Conclusion

Bird strike data at Ben-Gurion International Airport over the last decade have been presented here. When compared with the data for a five-year period that had been presented at the Madrid meeting, it is apparent that the number of bird strikes and their distribution according to season, species, altitude, flight stage, time of the day, and aircraft part struck has not changed significantly during the last five years.

FOOD PREFERENCE OF THE CHUKAR PARTRIDGE AND DOMESTIC PIGEON AT MILITARY AERODORMES IN ISRAEL

BATYA PELED

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INTRODUCTION:

The Alectoris chukar(chukar) and the Columba domestica (pigeon) are common resident birds throughout Israel including Air Force bases in the north,center and south of the country.The Israeli Air Force suffers significant aircraft damage due to strikes from these two species.

The chukar is a heavy (375-625 gr.) "clumsy" bird which escapes by running or low flight and is a hazard factor mainly during take off and landing.The chukar has a high breeding ability and few natural enemies within the bases. Often they appear in groups of 2-25 birds near or even on the runways.For that reason the chukar is a high hazard risk for multuple strikes.

Hundreds and thousands of pigeons cross some of the bases air space at least twice a day on their way from their resting areas to the feeding zones and back. They are an annoyance almost everywhere.Apart from the strike danger they also cause other damege to equipment and to public health.

CROP ANALYSIS:

In order to reduce the chukar and the pigeon populations in the bases we examined the abiotic and biotic factors of thier ecological habitats.One of the most important biotic factors is the food.
This subject was investigated by using controlled feeding stations and especially by the crop analysis of dead chukars and pigeons.
Knowledge of their food preference gives us the key to monisor the problem by:

* removal of prefered food.
* controlled agriculture.
* creating attractive points with the intention of traping the birds.
* weed elimination.

The crop is an elastic extention of the gullet functioning as primary storage and food digestion.The crop is an especially developed organ among seed eaters such as chukars and pigeons.It enables them to gather the food quickly.While in the crop the seeds are moistened and softened as the first step in digestion.

RESULTS:

figure 1-

* Wheat is the most preferable from the sowing period until sprouting. than,from the first stage of ripening through the spring,summer and autumn wheat seeds are the principal food.
* During the winter,when wheat seeds are rare,the most available food is green grass.
* Concerning vetch,although its spread is similar to that of the wheat,it is rarly found and then in small amounts.
* The Amaranthus seeds are very attractive to the birds despite their small size.
* During the spring and summer time we find considerable amounts of Notobasis and Sorghum which are very commen roderalic weeds at the bases.

figure 2-

* At controlled feeding stations we have found a clear preferance of sorghum seeds and wheat seeds compared to vetch.

figure 3-

* During one day of pigeon hunting in March 1992,at a base in an arid area,we found inside 95 out of 100 crops cooked food that originated from the base kitchen (spagheti,corn, chick-peas,potatos,chicken etc.).
This is a very alarming finding considering the efforts to decrease pigeon population by means of food control.

APPLICATION:

* Wheat was reduced.
* Vetch and oat areas were increased.
* Notobasis,Amaranthus and Sorgum eliminated as much as possible.
* Garbage disposal areas were put under strict supervision to avoid any organic refuse.

Figure 1

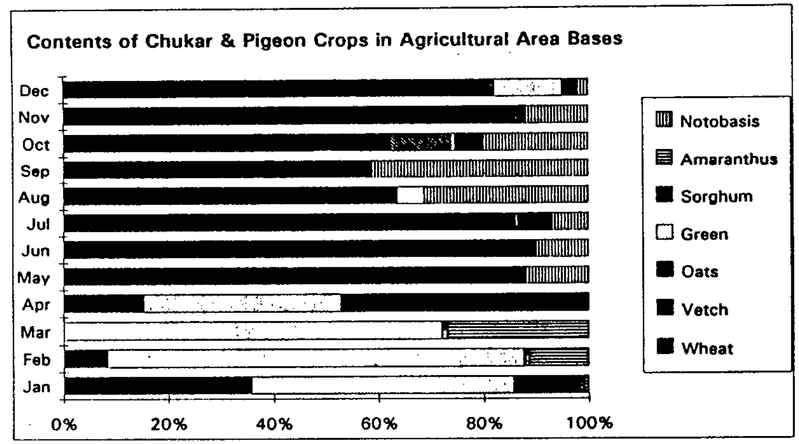


Figure 2

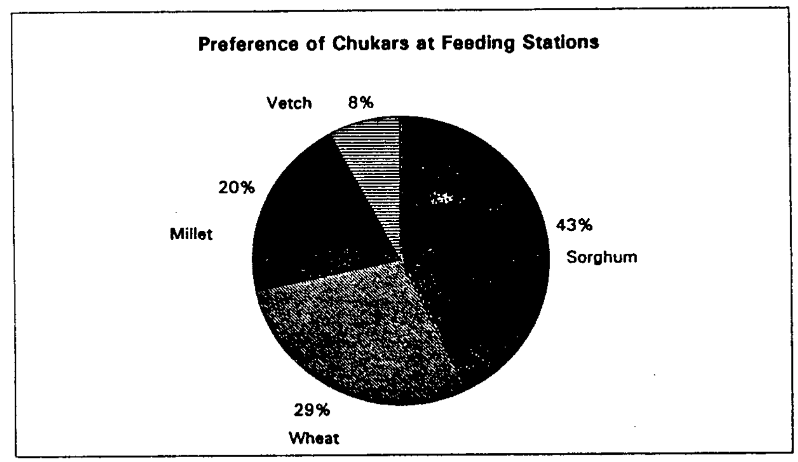
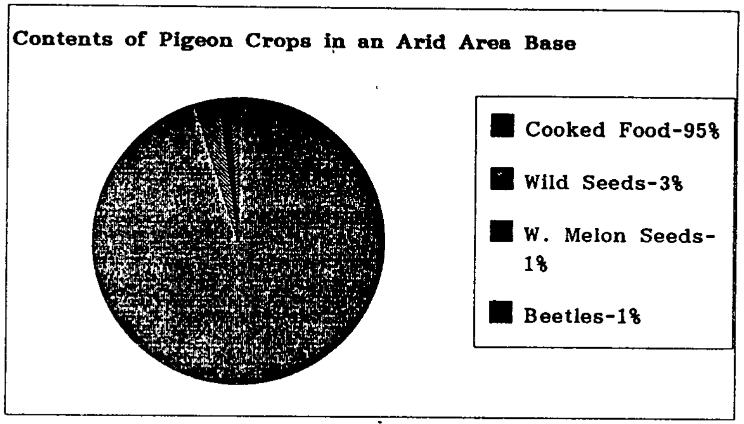


Figure 3



BSCE 21/WP/37
Jerusalem, 23-27 March 1992

RISK ANALYSIS OF BIRDSTRIKES ON VIENNA AIRPORT

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ABSTRACT

On recommendation of the Austrian Federal Ministry of Public Economy and Transport the "Flughafen Wien Betriebsgesellschaft m.b.H." (Vienna International Airport Authority) decided to start a program to reduce the risk of birdstrikes. One major step was an investigation of the quantity and distribution of birds on the area of and around Vienna Airport. The investigation period was one year.

As a result of this analysis four major items are in process to be improved to reduce the hazard of birdstrikes within the area around Vienna Airport. Another counter measure which is tested is the introduction of falconers.

RISK ANALYSIS OF BIRDSTRIKES ON VIENNA AIRPORT

The birdstrike-rate on Vienna International Airport (VIE) is in the international average. Until 1989 fire crackers of various intensity and effect have been the only counter measures against birdstrikes. Therefore the Federal Ministry of Public Economy and Transport, Department of Civil Aviation (MOT) forced the "Flughafen Wien Betriebsges.m.b.H." (FWB), who is operator of the Vienna International Airport, to start a program for avoidance of birdstrikes. In early 1989 a department of safety and security was founded in the course of a reorganization of the FWB.
After several meetings an agreement was made to establish an extensive anti-bird strike program.

Members of the airport staff visited in September 1989 Manchester Airport, where Dr. Thomas Callum has set up a successfull program to reduce birdstrikes, to obtain first information how to tackle a problem like this.

As a result of this trip the VIE security-people introduced the use of "stress call tapes" and bird mock-ups, which are thrown in the air, to frighten birds as a first measure.

For an effective reduction of birdstrikes the counter measures have to be adapted to the special conditions and circumstances on Vienna Airport. To obtain the necessary statistical data an analysis was initiated. In April 1990 the ornithologist Dr. Maria Elisabeth Wolf was contracted to provide a study about the risk of birdstrikes on Vienna Airport.

Within an observation-period of one year Mrs. Wolf made more than 100 times a preselected tour through the area of and around Vienna Airport. Records of all observations were put into specially designed forms. The aim of this analysis was to record the quantity and distribution of birds split up in different bird species, areas, seasons etc. in comparison with the bird strikes which occured. Also movements and habits of the different bird species have been observed.

The information and statistical data of this investigation was summarized in a report showing also some graphic representations of the analyzed subject. Resulting from the collected data there are four main items which have to be improved. The following paragraphs will indicate a short description of those items and the correspondig actions taken.

1) <u>Garbage Dump</u>

In the vicinity of Vienna International Airport a garbage dump is located. A strongly increased birdstrike-rate and a very high bird population was always observed within this area.
The FWB contacted the operator of this garbage dump. Together they set up quick first counter measures e.g. gas cannons. Also a shooting of birds in some cases is taken into consideration.

In 1993 a new law concerning waste utilization is planned to be put in force. This law will specify, that organic material (attractive for birds) has to be seperated from other material. For the utilization of the organic waste (production of compost) a new building should be used. This building is secured against birds by means of nets where applicable. This would be a remarkable improvement of the present situation.

2) Birds' Nests

The airport operator is trying not to affect the natural environment more than necessary. Therefore a lot of trees and bushes which serve as breeding place for several bird-species can be found in many parts of the airport area. During winter 1991/92 approximately 100 birds' nests have been removed. This action should grant, that the bird-population on the area of the airport and its vicinity will be reduced.

3) Termination of agricultral utilization:

Presently 165 hectares of land, which form approximately 16 % of the total area, are used for agricultural utilization within the area of Vienna Airport. These places have (especially when sowing or harvesting is in progress) a high attractivity for various bird species.
The airport operator has therefore developed a schedule to reduce stepwise the agricultural areas. As a first measure the leasing contracts with the tenant farmers of those fields, where the highest birdstrike rates have been observed, were terminated. These fields will be cultivated with long grass. In the future it is planned to cultivate all of the agricultural utilized areas with long grass.

4) Long Grass

The adoption of the long-grass-methode has already been started during the observation-period of Mrs. Wolf. This happened in close co-operation with the "Department of Ecology and Municipal Service" of Vienna Airport.
The adoption is done step by step and is still in progress.

Additional to those above mentioned counter measures against birdstrikes the FWB has made experiments to frighten birds away by means of falconery. The airport operator made these tests due to an offer of a falconer, who made his falcons available to frighten birds.
Until now it was not possible to give a reliable statement concerning the effectivity of this method.

Summary

All the above mentioned actions and measures show that many efforts have been undertaken to improve the present situation. As a result of the various activities the reduction of birdstrikes in future is expected.

In case of any questions or need for further detailed information of the actions taken in Austria don't hesitate to contact the Austrian representative under following address:

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BSCE 21 / WP 30
Jerusalem, 22-27 March 1992

A Simple Risk Model For Assessing Bird Strike Potential

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ABSTRACT

A simple risk algorithm was developed to assess the potential for serious bird strikes at US Air Force installations within continental US. The model computes a relative risk using five variables that describe each installation's mission, aircraft type , geographical region, regional bird hazards, and local bird hazards. The model ranked installations with known hazards at the top of the hazard list and placed installations known not to have serious hazards near the bottom. A significant statistical correlation was found between the computed risk value for each installation and the average number of strikes reported over the past six years.

A Simple Risk Model For Assessing Bird Strike Potential

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Introduction. Since 1985 over 14,500 bird strikes have been reported to US Air Force aircraft worldwide. Of these strikes approximately 60% have occurred in the vicinity of the aerodrome. With over 100 installations within the continental United States, prioritizing bird strike reduction efforts is a challenging task. In an effort to identify those installations with the greatest potential for a serious bird strike, the BASH Team developed a model to assess bird strike hazards. The Airfield Risk Assessment Program (ARAP) was designed to be independent of the number of reported strikes at each installation. We believe that any risk assessment effort that included reported strikes could lead to a decrease in reporting, rather than an improvement in bird control or avoidance. ARAP allows for relative comparison of risk at installations as well as for a relative assessment of the impact of changing weapon systems and changes in the local landuses. The BASH Team uses this program to prioritize on-site technical assistance and to assess other community planning issues.

Components of the Airfield Risk Assessment Program. ARAP has five basic components; aircraft type, installation mission, bird types, geographical region, and local hazards (Fig 1). The first, aircraft type, is a measure of aircraft vulnerability, and assigns a value to each aircraft according to the probability of being involved in a Class A mishap (loss of aircraft, aircrew fatality, or over 1 million US dollars in damage). This value was assigned based upon the number of Class A, B, and C mishaps, the total number of reported strikes, and the total cost of these strikes, reported over the past five years. Aircraft vulnerability is also dependent on aircraft design; for example the number, location, and type of engines. These factors were combined to determine a value on a 1 to 10 scale (Table 1).

The second component of the program is the primary flying mission at the installation. This value is based upon the amount of airfield traffic (aircraft exposure), and the experience level of the aircrew. For example, an Undergraduate Pilot Training (UPT) base is given a value of 10 due to extensive airfield traffic and the low experience level of student pilots. Replacement Training Units (RTU) for fighter aircraft also have intensive use of the airfield, but with slightly greater aircrew experience (Table 2).

The third component includes values for six general categories of birds (Table 3). These birds have been

AIRPORT RISK ASSESSMENT PROGRAM

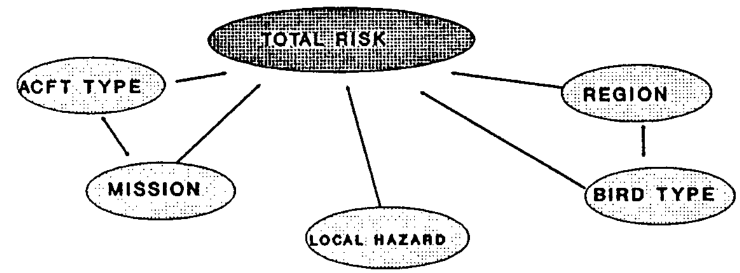

Fig 1. ARAP Program Components

AIRCRAFT TYPE

AC_TYPE	VALUE	AC_TYPE	VALUE
F-4	4	C-5	2
F-5	10	C-130	1
F-15	5	C-12	1
F-16	8	C-21	2
F-117	?	C-22	1
F-111	4	C-23	1
T-41	1	C-141	2
T-37	3	C-17	3
T-38	10	A-10	3
T-39	4	E-3	2
T-43	3	E-4	2
B-1	2	U-2/TR-1	5
B-2	?	C-9	1
B-52	1	KC-10	2
		KC-135	2

Table 1. Aircraft Vulnerability

MISSION	VALUE
UPT	10
RTU-FIGHTER	8
RTU-HEAVY	5
STRATEGIC/AIRLIFT	3
STRATEGIC/LOCAL	4
TACTICAL	6
TACTICAL AIRLIFT	4
HELICOPTER	1

Table 2. Installation Mission

BIRD TYPE	VALUE
RAPTOR	8
GULL	10
WATERBIRDS	3
BLACKBIRD	6
DUCKS/GEESE	7

Table 3. Hazardous Bird Types

identified as hazardous due to their size, flocking behavior, and affinity for airfields. Additionally, these birds have been identified in bird strike reports, and are the most common in strikes resulting in serious damage.

The fourth component of ARAP is geographical region. This factor is based on the distribution, and abundance of hazardous bird species in different regions of the United States. We divided the country into six regions and the coastlines (Fig 2).

The final component of the program includes the impact of known local hazards or bird attractions in the vicinity of the airfield. The assigned value includes both the type of hazard and the distance between the hazard and the runway (Table 4).

The Risk Algorithm. Initially, we simply added each component of the model, normalized the values and ranked the values produced for each installation. A close look at the results lead us to include the interaction of aircraft type and installation mission and the summation of the interaction of geographical region with each bird type (Table 5). This interaction more reasonably described the risk we were aware of at the installations that we had recently visited. This manipulation, however, resulted in the local bird hazard values contributing very little to the overall risk assessment. To compensate for this error, we multiplied these values times 10 to allow this component to contribute to the risk assessment. Data were entered for each installation into a Statistical Analysis Software (SAS) data file, and the risk value was determined for each installation. All values were normalized as a percent of the highest risk value determined to create a 0 - 100 scale. The final equation for risk was: Risk = ((local hazard x 10) + (aircraft type x installation mission) +(bird type x region))/(232.5) x 100.

Results. A ranked list of installations was output product of the analysis program (Table 6). We were curious if the computed risk were reasonable assessments, and polled three independent experts who had extensive on-site experience at these installations. We asked each to provide us a list of the five most hazardous and five least hazardous Air Force installations. In all cases the computed risk assessments captured the top five installations provided by the experts within the top ten computed values, and the least hazardous installations fell with in the lower ten computed values. A statistical analysis was executed to determine if reported strikes, an independent variable from the risk value, was correlated to the risk value. A significant correlation ($r= 0.36$ $p=.003$) was found between the computed risk and the average number of strikes reported over the past six years. Risk values were also analyzed using a stepwise regression analysis to determine which factors in the model contributed

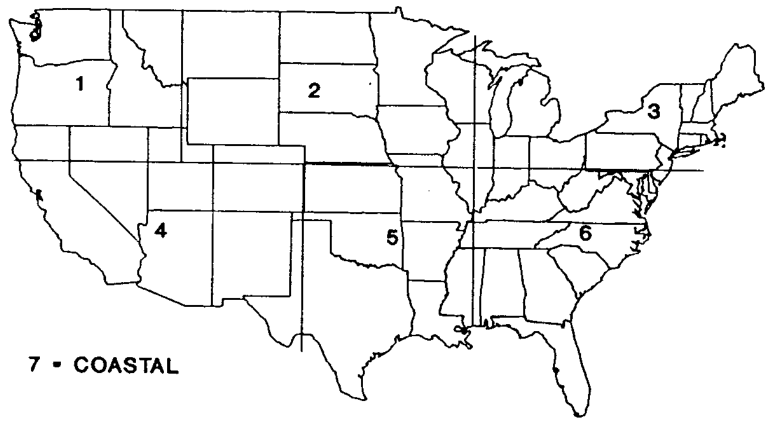

Fig 2. Bird Distribution Regions

REFUGE (W/IN 10 MILES)	6
LANDFILL (W/IN 2 MILES)	10
LANDFILL (W/IN 5 MILES)	7
LAKE/POND (W/IN 2 MILES)	4
LAKE/POND (W/IN 5 MILES)	2
WETLAND (W/IN 5 MILES)	3
BIRD ROOST (W/IN 2MILES)	2
AGRI OUTLEASE	1
DEER/MAMMAL HAZARDS	2

Table 4. Local Hazards

REGION	RAPTOR	GULL	WATERBIRDS	BLACKBIRDS	DUCKS/GEESE	TOTAL
1	1	0	1	1	1	24
2	1	1	1.5	2	2.5	52
3	1	2	1	1	1	44
4	2	0	1	2	1	38
5	3	1	2.5	5	3	92·5
6	3	1	1.5	5	1	75·5
7	3	5	3	0	3	104

Table 5. Summation of Bird/Region Interaction

BASE	RISK	AVG STRIKES/YEAR
REESE	100.000	34.8333
LAUGHLIN	95.699	37.0000
BERGSTROM	93.118	3.0000
RANDOLPH	91.398	52.8333
DOVER	90.323	17.8333
COLUMBUS	82.796	49.8333
SHEPPARD	82.796	44.1667
VANCE	82.796	48.6667
MACDILL	82.581	18.3333
TINKER	69.032	15.0000
TYNDALL	66.237	6.6667
HOMESTEAD	65.376	11.1667
WESTOVER	65.376	2.3333
BARKSDALE	63.011	56.0000
WILLIAMS	59.355	42.1667

Table 6. Top 15 USAF Installations (CONUS)

the most to the variation in risk. The results of this analysis suggest that geographical region and bird type had the greatest influence, followed by aircraft type, local hazards, and installation mission.

Summary. The Airfield Risk Assessment Program is a simple tool that identifies installations with the highest probability of a serious bird strike. The program is independent of reporting or on-site control programs and serves only as a relative assessment of factors such as mission, aircraft, geographical location and local bird hazards. The program allows management to focus attention and efforts on the installations with the greatest potential risk, and to assess future changes in mission and landuse.

BSCE 21 / WP 39
Jerusalem, 22-27 Mar 1992

Ultrasonics as a Method of Bird Control

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ABSTRACT

The potential users of ultrasonic bird repelling devices are many and include: All branches of the military, airfield managers, biologists, pest control/maintenance employees, government agencies (the Federal Aviation Administration, the US Department of Agriculture), agri-/aquaculturalists, aircraft manufacturers, and homeowners. A literature search conducted to find reports addressing the efficacy of ultrasonic bird repelling devices (UBRDs) revealed several substantial efforts. This report compiles and presents the results of the literature search. Avian hearing physiology, ultrasonic sound characteristics and the physical effects of ultrasonics on biological systems are addressed.

(ULTRASONICS, BIRD, AIRCRAFT, BIRD STRIKE, COLLISION AVOIDANCE, BIRD HEARING, BIRD CONTROL, ULTRASONIC EFFECTS, ULTRASONIC RESEARCH)

1. INTRODUCTION

This report was prepared by the Aircrew Protection Branch, Vehicle Subsystems Division, Flight Dynamics Directorate, Wright Laboratory, Wright-Patterson Air Force Base, Ohio. The effort was performed in-house in support of the USAF Windshield Systems Program Office, USAF Bird/Aircraft Strike Hazard (BASH) Team, and other potential users of an effective device for bird control. The report was written from September to December 1991, by David M. Hamershock, Aircraft Flight Hazard Analyst, Windshield Systems Program Office.

The objective of this report is to assist potential users of UBRDs by providing a principal source of information addressing their efficacy. Potential users of an effective UBRD are many and include: All branches of the military, airfield managers, biologists, pest control/maintenance employees, government agencies (the Federal Aviation Administration, the US Department of Agriculture), agri-/aquaculturalists, aircraft manufacturers, and homeowners.

The USAF, one potential user of an effective UBRD, could repel birds from the airfield environment, preventing hazards to aircraft saving millions of dollars per year. Inhibiting birds from nesting and roosting around static aircraft, aircraft hangars and facilities where they cause disturbing noise, maintenance, corrosion and health problems also can result in saving the USAF money. Since 1987, the USAF has lost six lives, and averaged a loss of $65 million for 3500 aircraft bird strikes each year (Ron Merritt, USAF BASH Team). 60.3% of reported USAF aircraft bird strikes occur in the airfield environment (Fred Samec, USAF BASH Team [Figure 1]), therefore, finding a method that will lower or evacuate bird populations from the airfield environment is desirable to the USAF.

USAF safety, pest control, base operations, and airfield maintenance personnel often seek methods of repulsing birds from presenting problems to aircraft, airfields, and base facilities. The use of ultrasonics was identified as a possible means of keeping birds away from base facilities or warning them of the approach of an aircraft. If UBRDs can control birds, then US Air Force base bird control and aircraft bird strike problems could be reduced through their applications.

UBRD manufacturers characterize their products as "scientifically sound, humane, inexpensive, and easy to operate" (Bomford and O'Brien 1990) means to deterring birds from inhabiting areas desirable to them. Some UBRD manufacturers also maintain that their mechanisms create unbearable physical stress to a birds' entire body, forcing the bird to flee from the treated area. From medical research, some is known about the possible damaging effects of ultrasonic sound on living organisms at the cellular and tissue levels (Gordon 1967a), but the actual behavioral effects to birds are unknown except for claims

advertised by UBRD manufacturers. Bird-X Inc. (730 West Lake Street, Chicago, Illinois 60606) advertisements claim that their UBRDs emit sounds that are: "Physically harmless, but birds can't stand them . . ., modulations birds can't get used to, annoying, [but] can't injure birds . . ., [and] pitched exactly where they provide intense discomfort to most types of roosting birds."

It was the intent of this effort to establish a validated basis for accepting the manufacturers' assertions. The search for background material resulted in identifying a substantial diversity of investigations that makes further research at this time of questionable value.

2. ULTRASONIC CHARACTERISTICS

Any sounds over 20,000 Hertz (Hz) or cycles per second (cps) are designated ultrasonic. Bird sensitivities range from 0.05-29,000 Hz depending upon the species. Human (*Homo sapien*) sensitivity to sound is normally 16-24000 Hz (Brand and Kellogg 1939; Kreithen and Quine 1979; Schwartzkopff 1955a). Ultrasonic sounds, travel at 340 m/s at mean sea level, 15°C (59°F), and a density of 1.23 kg/m³ (Kuethe and Chow 1986; Blitz 1967). Under the right conditions there is the potential for UBRDs to repulse birds, given the known damaging effects that ultrasonics can incur.

Ultrasonic sound can create heat, chemical effects, radiation pressure, and nerve disruption within living cells and tissues. Collectively, these effects can cause lethal cell damages. Heat can be produced by ultrasound when it is of high frequency (approaching 1 MHz) and is focused. The heat can reach an intensity that can cause damage to cell components resulting in cell dissolution (Gordon 1967a).

Radiation pressure effects cause "streaming" (rapid fluid movement) within cells that in turn has a part in cell necrosis. Cell necrosis (destruction) can occur because of the rupturing of mitochondria (organelles within the cell responsible for converting energy to a form more usable to the cell) caused by ultrasonic irradiation during electron microscopy. The mitochondria break up, releasing molecules lethal to other components of the cell.

Chemicals effect biological entities when combined with ultrasonic irradiation by chemical reaction rates being accelerated to a point where the cell is chemically suffocated and is damaged (Gordon 1967a). Mutations to bird embryos have resulted from ultrasonic treatment to eggs during incubation (Gordon 1967b).

The greatest effects of ultrasonic sounds are on nerve tissues, since nerve impulses can be blocked along nerve fibers.

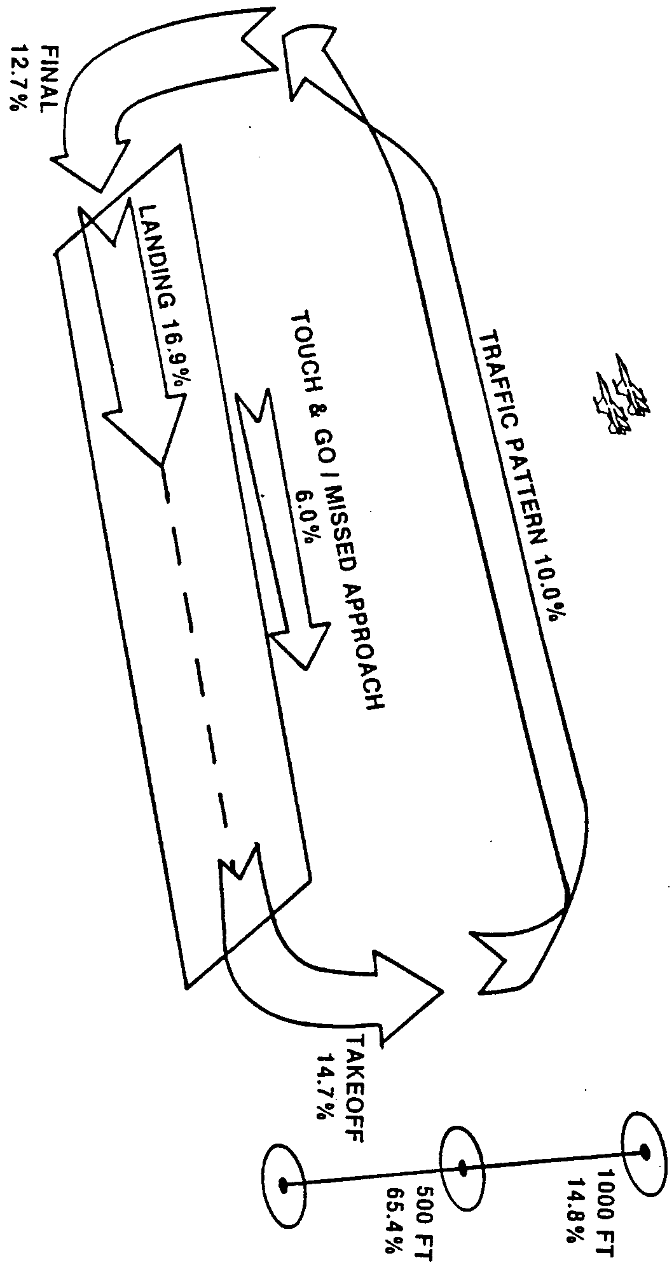


Fig. 1. Percentages of all US Air Force aircraft birdstrikes, by phase of flight within the airfield environment and by altitude (0 to 1000 ft AGL), from 1 Jan 85 to 31 Sep 91.

Permanent damage can result, causing loss of function of the parts of the organism for which the nerves have control. These effects occur in living tissues when ultrasound is applied at frequencies of 1-3 MHz from highly directional sources at extremely close distances (Gordon 1967a).

Ultrasound at levels above 140 dB has many effects upon humans. A loss of hearing sensitivity (temporary or permanent), pain, and sickness can result from constant or periodic exposure(s) (Beuter and Weiss 1986). It can be inferred that birds also have a threshold of intensity they can withstand before similar physical effects occur.

3. BIRD HEARING CHARACTERISTICS

Birds have an extraordinary sensitivity to sound. They have evolved with superior hearing ability to adapt to the higher levels of performance necessary to communicate, hunt, and navigate while in flight. Bird hearing requirements include excellent absolute hearing sensitivity, frequency perception, and time perception (Thorpe 1961). Optimum hearing performance for most bird species is achieved between 1,000 and 4000 Hz (Table 1). Upper limit hearing sensitivity can approach 30,000 Hz in some species (Meyer 1986). Most bird species do not exhibit significant hearing capabilities within the ultrasonic range (Schwartzkopff 1968).

In most cases, birds have greater hearing ability than humans. Birds can discriminate sonic frequency changes 10 times faster than man (Pumphrey 1961) and some (song birds) can produce and discern two modulated sounds or "notes" simultaneously. To the human ear these modulations sound like one note (Greenewalt 1968). Dooling and Searcy (1985) found that Budgerigars (*Melopsittacus undulatus*) have greater ability than humans to determine changes in frequencies. As occurs in humans, European Starling, House Sparrow (*Passer domesticus*), and Rock Dove/Pigeon (*Columba livia*) sound sensitivities have been found to decrease as they approach their upper frequency limit (Brand and Kellogg 1939).

Pigeons have exceptional low-frequency (infrasound) perception. Frequencies as low as 0.05 Hz have been discerned by Pigeons in a sound-isolated chamber. Doppler shift studies by Quine and Kreithen (1981) showed that Pigeons could detect a 1% frequency shift at 20 Hz and a 7% shift at 1 Hz. Infrasounds are produced by natural events such as thunderstorms, earthquakes, auroras, ocean waves, and mountain ranges, therefore, Pigeons may use these infrasound abilities to aide in navigation and weather perception (Kreithen and Quine 1979).

Table 1. Sonic reception range of various birds.

Species	Lower limit (Hz)	Most sensitive (Hz)	Upper limit (Hz)	Reference
Mallard *Anas platyrhynchos*	300	2000-3000	8000	Trainer (1946)
Canvasback *Aythya valisineria*	190		5200	Meyer (1986)
Rock Dove/Pigeon *Columba livia*			12000	Wassiljew (1933)
	50	1800-2400	11500	Wever & Bray (1936)
	200		7500	Brand & Kellogg (1939)
	300	1000-2000	5800	Trainer (1946)
	300	1000-4000	5500	Heise (1953)
			5600	Stebbins (1970)
			7300	Harrison & Furumoto (1971)
			5600	Heinz, *et al* (1977)
	0.05			Kreithen & Quine (1979)
	5		8000	Beuter & Weiss (1986)
Turkey *Meleagris gallopavo*			6600	Maiorana & Schleidt (1972)
Barn Owl *Tyto alba*			12500	Konishi (1973)
Long-eared Owl *Asio atus*	100	6000	18000	Schwartzkopff (1955a)
Great Horned Owl *Bubo virginianus*	60		7000	Meyer (1986)
			7000	Trainer (1946)
Eagle Owl *Bubo bubo*	60	1000	8000	Trainer (1946)
Greenfinch *Chloris chloris*			20000	Granit (1941)
European Robin *Erithacus rubecula*			21000	Granit (1941)

Species	Low. Lim. (Hz)	Most sensitive (Hz)	Upper Limit (Hz)	Reference
American Crow *Corvus brachyrhynchos*	300	1000-2000	8000	Trainer (1946)
American Kestrel *Falco sparverius*	300	2000	10000	Trainer (1946)
			7400	Dooling (1982)
Chaffinch *Fringilla coelebs*	200	3200	29000	Schwartzkopff (1955a)
Ring-billed Gull *Larus delawaren*	100	500-800	3000	Schwartzkopff (1973)
Red Crossbill *Loxia curvirostra*			20000	Knecht (1940)
Budgerigar *Mellopsittacus undulatus*	40	2000	14000	Knecht (1940)
		1800-3800	10000	Dooling & Saunders (1975)
Horned Lark *Eremophila alpestris*	350		7600	Meyer (1986)
House Finch *Carpodacus mexicanus*			7200	Dooling, *et al* (1978)
House Sparrow *Passer domesticus*	675		11500	Brand & Kellogg (1939)
			18000	Granit (1941)
	675		18000	Summers-Smith (1963)
Brown-headed Cowbird *Molothrus ater*			9700	Heinz, *et al* (1977)
Red-winged Blackbird *Agelaius phoniceus*			9600	Heinz, *et al* (1977)
Field Sparrow *Spizella pusilla*			11000	Dooling, *et al* (1977)
Ring-necked Pheasant *Phasianus colchicus*	250		10500	Meyer (1986)
Black-billed Magpie *Pica pica*	100	800-1600	21000	Schwartzkopff (1955a)
Snow Bunting *Plectrophenax nivalis*	400		7200	Meyer (1986)

Species	Low. lim. (Hz)	Most Sensitive (Hz)	Upper limit (Hz)	Reference
Bullfinch *Pyrrhula pyrrhula*			21000	Granit (1941)
	100	3200		Schwartzkopff (1949)
	200	3200	25000	Schwartzkopff (1952)
Canary *Serinus canaria*	1100		10000	Meyer (1986)
	250	2800	9600	Dooling, *et al* (1971)
Cape Penguin *Spheniscus demersus*	100	600-4000	15000	Wever, *et al* (1969)
Tawny Owl *Strix aluco*	100	3000-6000	21000	Schwartzkopff (1955a)
Gull (Species unknown)	50		12000	Beuter & Weiss (1986)
Blue Jay *Cyanocitta cristata*			7800	Cohen, *et al* (1978)
European Starling *Sturnus vulgaris*	700		15000	Brand & Kellogg (1939)
		2000		Trainer (1946)
			8700	Dooling (1982)

3. EXPERIMENTAL SUMMARIES

3.1 Experimental Summary # 1

Efficacy Testing of an Ultrasonic Bird Repeller
Richard E. Griffiths (1987)

Materials and Methods

Phase 1. Selected two areas with high levels of bird activity. Baited one area and observed it until bird feeding levels off. Recorded number of birds, species composition, and duration of visits for five days. Actuated the ultrasonic device, and recorded bird data until their behavior stabilized. Repeated for the second area, except without the ultrasonic device, to provide a control. A decrease in recorded activities suggested repellency. No change suggested ineffectiveness. A change in, followed by a return to, normal behavior signified habituation.

Phase 2. Repeated Phase 1, except used two other study sites and used the ultrasonic device before baiting.

Phase 3. Repeated Phase 1, except used two other study sites and moved the ultrasonic device from the treatment to the control site after a sufficient amount of time.

A 10-minute sampling interval was chosen. Observations were randomly accomplished during daylight hours. Feeding time was measured by timing randomly selected individual birds from the time they arrived to the test site to the time they departed. Sunflower seeds were inserted into cylindrical plastic bird feeders as bait. The feeders were 6 cm in diameter, 40 cm long, and hung from tree limbs approximately 2 m above the ground. Seed consumption was determined by measuring the height of the seeds remaining in the feeders at dusk, each day and subtracting their volume from the total capacity of the feeder.

The UBRD used, manufactured by Bird-X, Inc. (730 West Lake Street, Chicago, IL), could produce a complex mixture of sonic and ultrasonic sounds. It was a small (8 x 8 x 12 cm) aluminum box with a pulsed output in three ranges: 5 to 50 kHz (low pitch), 1 to 50 kHz (loud pitch), and 20 to 50 kHz (high pitch). It had an average peak output of 112 dB measured at 0.3 m. It also had settings for what the manufacturer called a "high rate modulation frequency" (mode) at 0 Hz (A), 1 kHz (B), and 4 kHz (C) for a total of nine possible sound outputs. Graphic representations of the principal sound outputs tested (high pitch-C mode and loud pitch-C mode) as measured by a model 660B Nicolet analyzer are shown (Figs. 2 and 3). The manufacturer's instructions claimed effective outdoor coverage within an area 30 m long and 22 m wide.

Phase 1 test sites were baited in mid-October 1985. In mid-November the ultrasonic device was activated, the high pitch-C mode tested first and the loud pitch-C mode second. The ultrasonic device was placed 9 m from the feeders.

At the Phase 2 test sites, the ultrasonic device was activated in early October 1985. The feeders were baited two weeks later The ultrasonic device was placed 3 m from the feeder. Phase 1 type tests (bait before ultrasonics added) were completed in January and February 1986 at this site, except the treated and control site observations were made alternately.

Phases 1 and 2 were both conducted in forest-edge habitat in northeastern Maryland. Both phases did not consider the occurrence of individual birds leaving and returning the test areas during observation periods.

Phase 3 testing was completed using high, low, and loud pitches in the A, B, and C modes at a southeastern Virginia warehouse site in June 1985. House sparrows (*Passer domesticus*) were tested that were perching on electrical wires before

FIGURE 2. Ultrasonic device sound output, loud pitch C-mode; an average of 100 pulses were measured at 0.6 m.

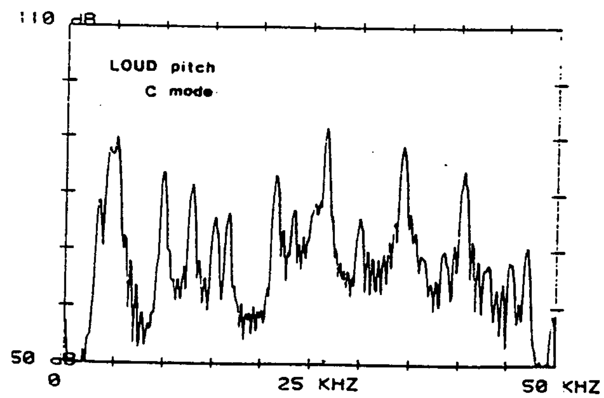


FIGURE 3. Ultrasonic device sound output, high pitch C-mode; an average of 100 pulses were measured at 0.6 m.

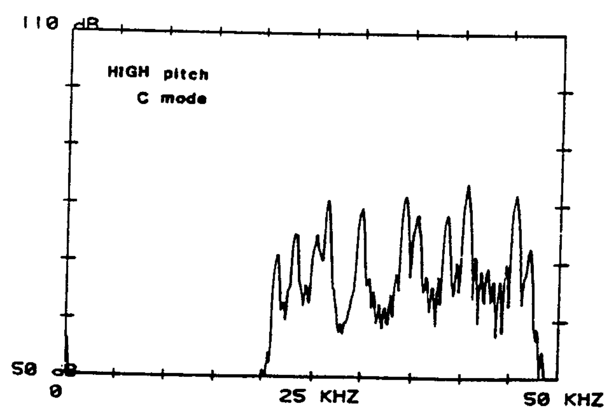


TABLE 2. Average feeding time in seconds by species and treatment based on approximately 100 observations per species per treatment.

	Treatment				
Species	Pre-treatment (Nov)	High C (Dec 1-10)	Loud C (Dec 12-25)	Post-treatment (Jan)	Control (Nov-Jan)
H. Finch	50	40	23	12	31
Junco	112	48	111	45	28
Chickadee	4	3	2	3	12
Nuthatch	16	5	10	2	21
Blue Jay	7	3	4	10	8

TABLE 3. Average sunflower seed consumption (in ml) per day by treatment.

	Treatment			
Location	Pretreatment (Nov)	High C (Dec 1-10)	Loud C (Dec 12-25)	Posttreatment (Jan)
Test Site	1872	1954	2098	1230
Control Site	1015	1260	1153	1276

entering the warehouse. No baiting was executed.

Results

Species recorded feeding at the Phase 1 and 2 test sites included the House Finch (*Carpodacus mexicanus*), Dark-eyed Junco (*Junco hyemalis*), White-breasted Nuthatch (*Sitta carolinensis*), Tufted Titmouse (*Parus bicolor*), Black-capped Chickadee (*Parus atricapillus*) and Blue Jay (*Cyanocitta cristata*).

Phase 1 testing resulted in decreased average feeding time at the treated site for all species during high pitch-C mode operation. When the device was switched to loud pitch-C mode operation, further decrease in House Sparrow and Chickadee

TABLE 4. Average number of birds arriving at the test site per 10-min interval.

Principal Species	Treatment: Post-treatment (Nov)	High C (Dec 1-10)	Loud C (Dec 12-25)	Post-treatment (Jan)	Control (Nov-Jan)
H. Finch	61.6	69.9	91.5	54.0	12.8
Junco	5.6	6.4	5.1	10.2	3.8
Chickadee	3.2	3.3	3.6	2.2	7.9
Nuthatch	0.1	0.8	2.3	2.3	1.9
Blue Jay	0.3	1.4	2.6	6.3	17.6
All * Species	70	82	105	79	48

* Principal and occasional species.

feeding time was recorded (Table 2). Feeding time for all species except Blue Jays remained below pretreatment levels for the month following the tests. Feeding times were highly variable and appeared to be influenced more by inter- and intraspecies conflicts than by the ultrasonic device. Food consumption was not affected by either treatment (P = 0.356 [Table 3]), and the number of birds visiting the site increased (P = 0.042). Control site measurements remained constant. Effects of weather changes were constant at both treatment and control sites.

Phase 2 activity and seed consumption levels were initially lowered after high pitch-C mode treatment commenced, however, the discrepancies disappeared over time. The mixed sonic-ultrasonic mode (P = 0.014) resulted in less bird visitation than the all ultrasonic mode (P = 0.037). The ultrasonic device was not moved during testing. The same birds had access to both the treated and control sites. Phase 3 testing resulted in no differences in house sparrow activity. Observed head movements indicated that they could perceive the low and loud pitches. Some sparrows even approached the device (from the side, not in front of the output speaker) to investigate it.

Discussion and Conclusions

Of all the sites and sonic combinations tested, the bird visitation rate was markedly affected only during the sonic-ultrasonic paired treatment. Neither the ultrasonic mode (above

20,000 Hz) or the ultrasonic/audible mode (1 to 50,000 Hz) significantly affected any of the species studied. The results indicate that the ultrasonic device would not work to keep the studied bird species away from an area attractive to them.

Activation of the ultrasonic device prior to the baiting of the feeder resulted in initial deterrence, however, once bait was available bird activity escalated. When control and test sites were interchanged the activity/seed consumption level remained constant. Recording the duration of feeding efforts was obscured by the occurrence of inter- and intraspecies interaction. Blue Jays frightened away all other birds, and sizable concentrations of finches deterred chickadees. House Finch feeding times inversely affected visitation rates. The decline of feeding time in January could have been caused, in part, by increased Blue Jay presence.

The use of time lapse photography would be useful for future experiments of this type. Greater accuracy, less required labor and fewer necessary funds would result.

It is doubtful that the tested device or other devices with like sound output can deter the studied bird species from inhabiting attractive areas. Unless further tests provide more favorable bird repelling results, the tested ultrasonic device is not recommendable (Griffiths 1987).

3.2 Experimental Summary # 2

Ineffectiveness of a Sonic Device for Deterring Starlings
MARY BOMFORD (1990)

Materials and Methods

A small test area without obstacles was selected, to provide an area without sound shadows. A 150 m circular area within a grassy field in Canberra, Australia was utilized. A 7 m high blind was at the midpoint (Fig. 4). The circle was divided by ribbons on pegs into 12 (30 degree) segments. Alternate divisions and a concentric inner circle (50 m radius from the midpoint) were selected as buffer zones. All the test area was either flat or gently sloping, therefore, easily visible from the blind. The grass was mowed upon commencement of the experiment (10 Apr 87).

Treated, buffer, and untreated (control) divisions were alternated around the circle. The ultrasonic device speakers were placed at the inner margins of the 3 treated divisions. Each division was divided into 2 parts: 50 m to 112 m and 112 m to 150 m (from the midpoint). These two subdivisions had areas of 2630 and 2607 (square meters) respectively.

The (Model 825) Hi-tec Electronic Scarecrow (Hi-tec Control

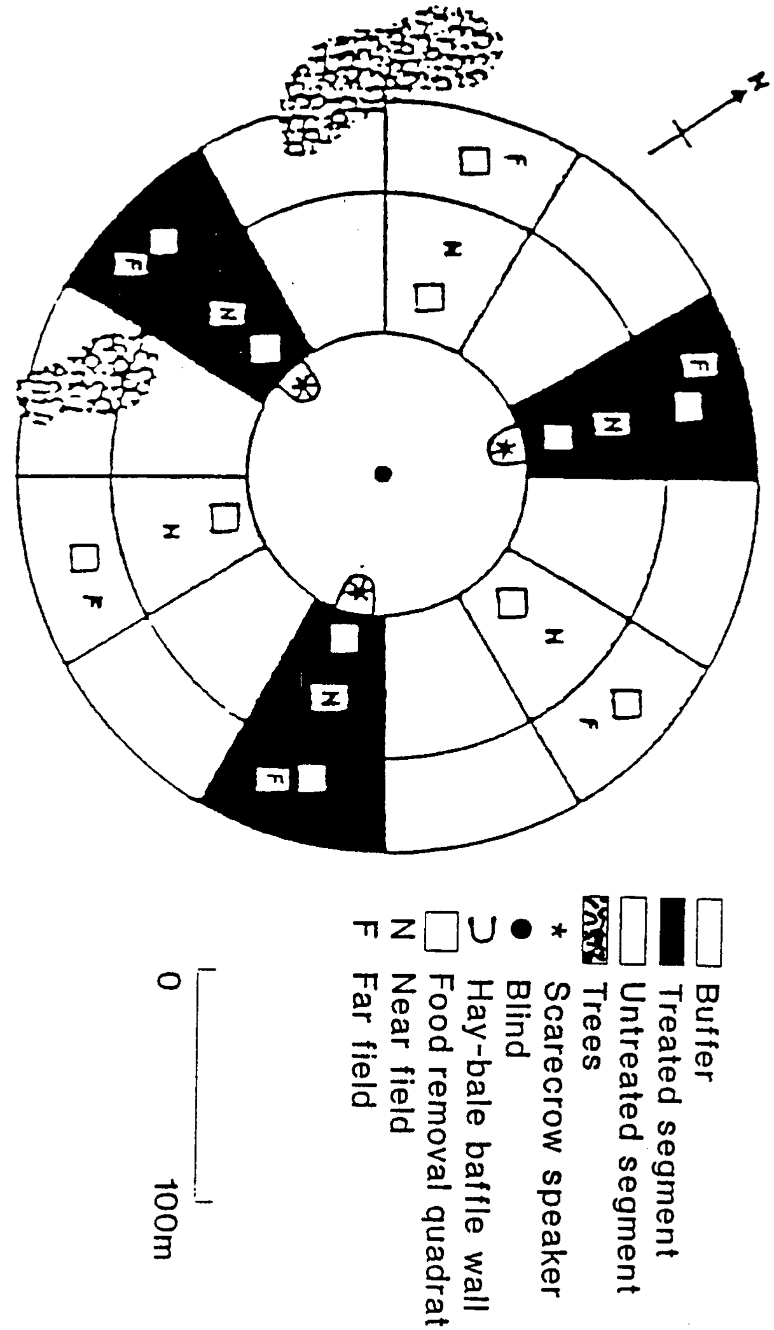


Fig. 4. Study plot for starling experiment with a sonic scarecrow, Canberra, Australia, 1987.

Syst. Propriety Ltd., Australia) was erected by a company representative on 30 Apr 87. The scarecrow consisted of a control unit with a programmable timer to which a number of remote speaker units were connected. The individual speaker units had 5 vertically mounted transducer heads producing the ultrasonic sound. Power was provided by a 12-volt long storage battery recharged by 2 (42 W) solar panels. Each speaker unit, held 1 m above the ground by a steel post, was focused toward the perimeter, along the central axes of each treated division. Barriers 2 m high, 0.4 m thick, and 5 m long made out of hay-bales were constructed behind and beside each speaker to restrict the ultrasonic sound dispersal to only the desired divisions. According to the manufacturer, each speaker will protect 4 hectares (nearly 8 times the area of one division). The automatic timer was set to operate the control unit from 0600 to 1800 each day. The sonic output of each speaker was measured using a sonograph (Kay digital sonograph 7800, Pine Brook, New Jersey).

Feeding quadrats (4 square meters each), with fruit and stale bread (bait) dispersed within, were 30 m from the inner margin of each subdivision. Bait placement from 13-23 Apr 87 served to interest European Starlings into the study area and to practice counting them. From 24 Apr-17 May 87, at 0900 each day, fresh bait consisting of 10 slices of white bread and 10 red apples (halved) were placed within each quadrat. At 1600 each day, bait remaining within each quadrat was collected and quantified to the nearest half (slice of bread or apple).

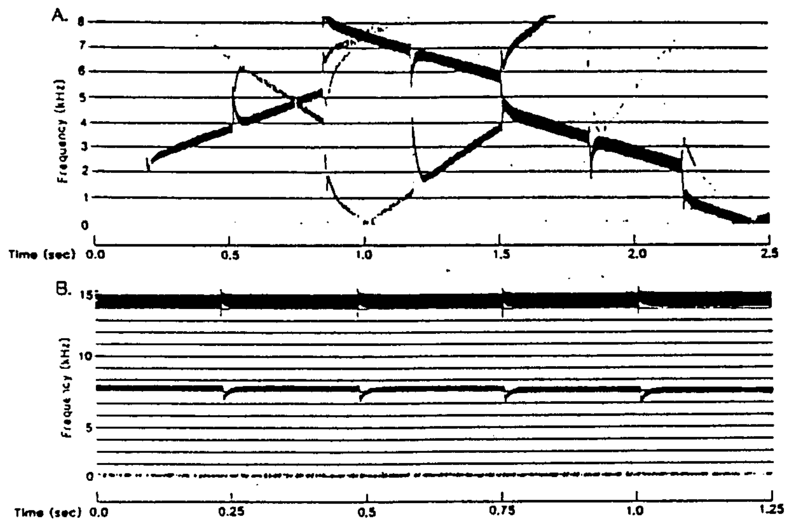
Individual starlings were counted, from the blind, using 10 x 40 binoculars. Large groups were approximated by "10, 20, or 50." Starting 24 Sep 87, counts were taken each day from 1500-1600. Each division was enumerated at 1 minute intervals, therefore, the 12 divisions were counted 60 times within the hour. On 6 May 87 the scarecrow was turned on and the counting continued through 17 May 87.

Three response variables were measured: Starling numbers, remaining apples, and remaining bread. The data was analyzed by a three factor analysis of variance including scarecrow (with and without divisions), distance (near and far divisions), and period (pretreatment and treatment) as factors. Before analysis, the data was averaged for the pretreatment and treatment periods. Plots of residuals for the three response variables (compared to an ordered distribution generated by the GLIM statistical package [Payne 1986]) were found to be normally distributed.

Results

The ultrasonic signal emitted from each speaker was highly directional in the vertical plane, encompass the entire 32 kHz range of the sonograph (a substantial amount of it above 16 kHz, the usual upper auditory limit for starlings [Schwartzkopff 1955,

FIGURE 5. Sound spectrogram of the glide-tone section (A) and pulsed section (B) of the signal emitted by a Hi-tec Electronic Scarecrow in the lower frequency ranges. Note that the time scale differs for the two records.



Frings and Cook 1964, Spear 1966]), and consist of a complex 6 second glide tone followed by 10 seconds of pulsed bands at several frequencies (Fig. 5). The glide/pulse sequence repeated continuously with frequency and pattern varying slightly each time.

Microphone readings taken in front of a speaker found the discharged sound to average 91 dB at 10 m, 76 dB at 30 m, and <71 dB at 50 m (by the 50 m point ambient sounds coming from a road and a research station 600 m away proved more intense).

Starlings feeding when the scarecrow was first operated did not appear startled, alarmed, or more alert. None of the birds evacuated immediately from the treated divisions. Within 5 minutes a flock of >500 starlings alighted and began feeding in

TABLE 5. Numbers of starlings and remaining apples and slices of bread, averaged for days and fields, in an experiment to test the effectiveness of a sonic deterrent device in Canberra, Australia, 1987.

Treatment (n = 3)	Number of starlings		Number of apples		Number of bread slices	
	x	SE	x	SE	x	SE
Treated segments						
Pretreatment period						
Near fields	793	195.5	7.5	0.23	3.3	0.40
Far fields	1307	368.9	6.2	0.93	2.8	0.93
Treatment period						
Near fields	1705	147.8	2.9	0.74	1.7	0.47
Far fields	1586	218.2	2.7	0.54	1.3	0.64
Untreated segments						
Pretreatment period						
Near fields	997	119.0	6.2	0.66	3.0	0.39
Far fields	1001	292.9	6.4	0.87	2.8	0.35
Treatment period						
Near fields	1638	321.5	2.6	0.54	1.2	0.42
Far fields	1197	360.6	3.0	0.86	1.6	0.72

front of a speaker. During the treatment period, starlings often alighted within 1 or 2 m of the speakers to feed. In comparison, when a helicopter, or bird of prey flew over, or a person approached, the birds would take off delivering audible alarm calls.

Starling numbers increased over the course of the experiment (Table 5) and were highest while the treatment period was being conducted (F = 6.40; 1,16 df; P = 0.022). During the treatment period, no significant differences in numbers between near and far divisions (F = 0.0005; 1,16 df; P = 0.98) or treated and untreated divisions (F = 0.63; 1,16 df; P = 0.44) occurred.

Other bird species occasioned all divisions and sometimes took bread: Australian Magpies (*Gymnorhina tibicen*), Australian Ravens (*Corvus coronoides*), and White-winged Choughs (*Corocorax melanorhamphus*). The number of non-starlings inside the test boundaries never exceeded 10 individuals, and was usually <5, compared to an average of 256 starlings, therefore, feeding by

other species should not have biased food removal assessments. Fewer bread slices ($F = 13.72$; 1,16 df; $P = 0.002$) and apples ($F = 55.31$; 1,16 df; $P < 0.001$) remained during the treatment period than during the pretreatment period. During the treatment period, no significant differences ($P > 0.59$) in food amounts remaining between near and far divisions or treated and untreated divisions occurred.

Conclusions

The Hi-tec Electronic Scarecrow had no effect on the number of and the quantity of food eaten by starlings visiting the 3 treated divisions. In the treatment period, starling numbers were 57% higher than the pretreatment period. Flocks of starlings flew through treated divisions to feeding quadrats without apparent hesitation or avoidance behavior (Bomford 1990).

3.3 Experimental Summary # 3

Effect of Ultrasonic, Visual, and Sonic Devices on Pigeon Numbers in a Vacant Building

PAUL P. WORONECKI (1988)

Materials and Methods

The Bird-X Ultrason UET-360 (Bird-X Inc., Chicago IL) ultrasonic bird repelling device was evaluated. The device was powered by 110-140 V, could be switched to emit either continuous or pulsed sounds, had an electronic oscillator tuned to 18,000 to 23,000 kHz, and was attached to a turntable that rotated twice a minute. The device output was measured by a B&K Precision Sound Level Meter placed directly in front of the device speaker at a vacant parking lot, within an enclosed metal building, and at 22 unobstructed test site positions.

The UET-360 was tested in a vacant power house building (PH-1) occupied by >70 pigeons at NASA, Plum Brook Station, near Sandusky, Ohio. The floor space of PH-1 was 704 m^2 (roughly 22 m x 32 m). The ceiling was 18 m high. The UET-360 advertisement claims that the bird repelling coverage exceeds 8,000 m^2, not including secondary coverage.

Other PH-1 features included an open network of concrete pillars, catwalks, platforms, stairs, and railings. Pigeon activity was limited to the upper 4.6 m of the building; nesting on the ledge of the interior wall and roosting on ledges, railings, pipes, and light fixtures. Most pigeons utilized a broken window at the southwest corner as an entrance and exit, which provided for a simple and accurate census.

The UET-360 was suspended by chains and cable 4.6 m from the ceiling. The device was 7.3 m from (and at the same elevation

TABLE 6. Sound level responses from an Ultrason UET-360 taken with a B&K Sound Level Meter at 3 m before, during, and after an evaluation conducted at Sandusky, Ohio, in October and November 1986.

	Sound level (decibels)			
	Continuous		Pulsed	
Location	Impulse	Peak	Impulse	Peak
DWRC (parking lot)	95	101	96	101
Sandusky (metal building)		100		101
Sandusky (Power House-1)		96		98

as) the ledge utilized for nesting, and 11.9, 7.3, and 18.6 m from the walls.

Testing was accomplished 8 Oct-26 Nov 86. The number of pigeons inhabiting PH-1 was counted by 1 person approaching the building's southwest corner (starting 46 m away). Birds leaving from and perched/nested inside the building were counted as the counter approached and entered the building. Nesting activity was also noted. These counts were made between 0730 and 1000 at least 3 times a week. Additional inspections were made at times other than scheduled to make note of any behavioral or activity changes resulting from the device.

The UET-360 was installed according to manufacturers instructions, therefore, all nests (including eggs, nestlings, and non-flying young) were removed before testing. The device was operated continuously for 20 days (20 Oct-7 Nov 86); 10 days pulsed output and 10 days continuous output. Sound output was measured again. The device was then switched off and pigeon numbers continued to be recorded for 10 more days.

Results

The continuous output was 19.2 kHz, with a slight amplitude modulation at 120 Hz. The device emitted 79 pulses per minute during the pulsed output at frequencies of 20-26 kHz. Sound level measurements taken at a distance of 3 m before, during, and after the experiment yielded similar results. The impulse sound

TABLE 7. Mean number of pigeons counted leaving Power House-1 during Ultrason UET-360 evaluation.

Dates	Treatment Period	Number of Pigeons $\bar{x}$	SD	Range	No. of Observ.
8-17 Oct	Pretreatment	64	8.2	52-73	5
18-28 Oct (b)	Pretreatment	66	21.0	31-89	7
29 Oct-7 Nov	Ultrasonic-Continuous	75	15.1	48-92	6
8-17 Nov	Ultrasonic-Pulsed	73	15.3	55-93	5
18-26 Nov	Posttreatment	71	16.7	51-93	7

levels were approximately 5 dB lower. The peak sound level measurements, taken at 22 locations inside PH-1 at distances of 3 to 28 m, varied from 73-98 dB. Levels in the area of pigeon roosting and nesting activity ranged from 73-98 dB for the pulsed output and 84-98 dB for the continuous output. In areas of PH-1 where the device was not visible, background levels from 70-73 dB were recorded. Sound pressure wave measurements revealed that the ultrasonic signals were easily shadowed by objects and that there were areas within PH-1 where the pigeons could easily elude the sounds.

A 10-day pretreatment period (8-17 Oct 86) of counts resulted in an average of 64 pigeons per observation (Table 7). A 11-day pretreatment period (18-28 Oct 86) testing the impact of nest removal and UET-360 presence (without being turned on) upon the PH-1 pigeon population, resulting in an average of 66 pigeons per observation.

UET-360 output in the "continuous" mode began on 29 Oct 86 at 0940 and lasted until 7 Nov 86. After the device was turned on (from a switch outside the building) 10 pigeons left the building within the first fifteen minutes. An average of 75 pigeons were present per observation.

The "pulsed" mode, was tested from 8-17 Nov 86. No change in pigeon presence was noticed as there was an average of 73 pigeons per observation. Four nests had been reconstructed during the treatment periods, 7.3-20.4 m from the UET-360. Eggs were found in the 4 nests when checked on 11 Nov 86 and by 17 Nov there was a total of 8 eggs being incubated.

During a 10-day posttreatment period, from 18-26 Nov 86, an average of 71 pigeons were observed. Two eggs had hatched by 26

Nov 86.

Discussion and Conclusions

The Ultrason UET-360 invoked neither an initial fright response, nor any reduction in pigeon numbers during the two 10-day treatment periods. Pigeons fabricated nests, laid eggs and incubated eggs 7.3-20.4 m from the device.

A sonic device, the Deva-Megastress II, and a visual device, the Deva-Spinning Eyes (both manufactured by Brakam Miller, Saltney Engineering Limited) both had some effect on pigeon numbers when tested within PH-1. The sonic device reduced numbers for 2 of 10 days, whereas the spinning eyes had repelling effects for only the first of 10 days.

The UET-360 failed to reduce the population, alter the behavior, and stop the nesting activity of pigeons within a vacant building. This study demonstrates that ultrasonic devices are ineffective in reducing pigeon populations (Woronecki 1988).

4. OTHER STUDIES ON ULTRASONICS

Meylan (1978) conducted an "ultrasonic" experiment resulting in high levels of bird repelling success. From mid-August to mid-September 1977, Meylan tested an ultrasonic device in a sunflower field in Switzerland. Damage to the crop was 40% less than normal during device operation. House Sparrows (*Passer domesticus*) and Tree Sparrows (*Passer montanus*) disappeared completely. Greenfinches (*Cardeulis cardeulis*) visited the crop singly and only for short time intervals during device operation. After the device was turned off the Greenfinches again fed "gregariously," and within a few days the crop was heavily damaged. The sound produced by the device consisted of one second pulses at 16,776 Hz (Table 8). This frequency level is approximately 3300 Hz below the "ultrasonic" range (Griffiths 1987). Meylan includes no description of his materials and methods to give greater credibility to his experiment. Important factors such as weather, migration, and other available food sources were not included.

Fitzwater (1970) described his experiences using ultrasonic bird repelling devices as "discouraging." He found that ultrasonic devices are expensive to purchase and operate, produce "sound shadows" (leaving areas untreated), and produce sounds that decrease rapidly in magnitude once they leave the source.

Martin and Martin (1984) researched the effects of ultrasound upon cormorants, gulls, and Rock Doves. The tested birds were using shipyard pier towers for roosting at night. The fecal remains left by the birds created a slippery hazard for dock employees and cleaning problems because of the sun baking

TABLE 8. Researchers, ultrasonic frequencies, birds, and results of experiments testing the performance of ultrasonic bird repelling devices.

Researcher	Frequency (kHz)	Bird(s) Tested	Results
Beuter & Weiss	20-50	Gull European Starling	No effect.
Bomford	20-32	European Starling	No effect.
Fitzwater			Discouraging expense, range, and performance.
Griffiths	20-50	House Finch Dark-eyed Junco White-breasted Nuthatch Tufted Titmouse Blue Jay	No effect, except for small effect during ultrasonic/sonic test.
Kerns	20-26	Cliff Swallow	No effect.
Martin & Martin		Cormorant Gull Rock Dove (Pigeon)	5% reduction in bird presence.
Meylan	16.8**	House Sparrow Tree Sparrow Greenfinch	House and tree sparrow populations reduced 100%. Greenfinches reduced significantly.
Theissen, *et al*	20	Peking duck (Mallard)	No effect.
Woronecki	20-26	Rock Dove (Pigeon)	No effect.

** Not considered an ultrasonic frequency.

them upon metal surfaces (of ships . . .). The ultrasonic devices were placed on top of pier towers and operated for 16 days straight. In comparison to a preultrasound measurement of birds present, there was only a 5% drop in birds present.

Beuter and Weiss (1986) tested UBRDs on gulls (Laridae) at a municipal purification plant. The UBRD emitted ultrasonic frequencies of 20-50 kHz at intensities of up to 135 dB. There was no indication that the gulls could either hear or be repelled

by the device. They did find that an efficient sound signal to scare the gulls had a frequency span of 2-7 kHz, frequency modulation of 0.5-20 Hz, duration of 20 s and minimum intensity of 60 dB. European Starlings also could be repelled by utilizing these signals.

Theissen, *et al* (1957) studied the effects of UBRDs on the feeding of Peking Ducks (selectively bred Mallards). After testing the feeding behaviors of 30 ducks within a pen, it was concluded that the ducks "do not respond to 20000 Hz sounds at intensities up to 130 dB."

Evaluation of the effectiveness of the "Ultrason ET" UBRD or Cliff Swallows (*Hirundo pyrrhonota*) was accomplished by Kerns (1985). The device lacked significant effect to controlling Cliff Swallow population size or behavior.

A pair of rotating 21000 Hz UBRDs were reported to have eliminated Rock Doves from roosting sites at a building in Florida, however, after a period of four months, habituation had occurred and the Rock Doves would perch atop the UBRDs without apparent discomfort (Dubco 1984 and Dugger 1984).

Bird-X, Inc. was invited to submit any research efforts completed by themselves or any other person(s) addressing the efficacy of UBRDs. Bird-X had no research efforts to submit, however, offered information from numerous records of UBRD customer satisfaction and success (telephone conversation with Mona Zemsky, Bird-X, Inc. Marketing Manager, January 1992). No information was available as to duration of time of UBRD success.

5. CONCLUSIONS

No UBRD experiments, to present, have resulted in a bird population reduction greater than 5%. The one experiment that had significant effect utilized a sub-ultrasonic frequency of 16776 Hz. Of the bird species that have had their hearing levels studied, most (26 of 33) do not have the capability of hearing ultrasonic sound (Table 1).

A bird cannot be physically stressed by an UBRD unless it can focus a frequency approaching/above 1 MHz to a birds' body or deliver a sound intensity of over 140 dB at the location of the birds' ear. The physical effects of UBRDs are minimized by the intensity, proximity, and focusing required to cause such effects. Of the UBRDs that have been tested, the maximum levels of emitted sounds recorded include a frequency of 50 kHz and an intensity of 135 dB.

UBRDs (as with most bird control devices) lose their effectiveness over time because birds habituate (get used) to the presence of their repelling qualities. Any sound which scares birds away is often effective only for a limited time, depending

upon the resolve of the bird species being treated. Birds will continue to inhabit busy, noisy, turbulent airfield environments as long as the benefits of available resources outweigh the stress, unpredictability, and threat of physical harm caused by a sonic repelling device.

The results of the research efforts referenced in the report make it difficult to conclude that the claims made by UBRD manufacturers are valid. One possibility for these results is that the tested UBRDs have been designed and advertised by the manufacturers to repel birds that cannot hear ultrasonic sound (Pigeons, European Starlings, Gulls, etc.). Since it is possible for some bird species to hear ultrasonic sound (Chaffinches, Bullfinches, Tawny Owls, etc.), it can be theoretically assumed that these species may be able to be repelled by an UBRD designed specifically for the control of them. Research focusing on bird species with known ultrasonic hearing capabilities may provide data that may improve UBRD performance to the point where an UBRD can selectively repel these species of birds (see Table 1).

This compilation of tests of UBRD performance should enable potential users to make improved decisions on the role of UBRDs in managing their bird control problems. The alternate "active" bird control methods sanctioned by USAF Regulation 127-15 (*The Bird Aircraft Strike Hazard [BASH] Reduction Program*) are: Pyrotechnics, bioacoustics, depredation, propane cannons, scarecrows, bird models, remote-control airplanes, and falconry. While delivering effective performances, these control techniques all have limitations, difficulties, and inefficiencies that result in the continuation of the aircraft birdstrike problem and other bird related problems. Before purchase, potential users of UBRDs should contact existing users of UBRDs to evaluate the duration of their bird control success.

6. RECOMMENDATIONS

The information available addressing the frequency perception ability of most bird species is incomplete and often repetitive. As of now only 33 of 9000 (both figures approximate) bird species have been tested to determine their hearing frequency limits, leaving a substantial amount of information yet to be recorded (Welty and Baptista 1986). Research accomplished to record the frequency sensitivities of many untested bird species should be continued. Emphasis should be placed on investigating a broad spectrum of bird classifications. These records would provide UBRD researchers and manufacturers with a more complete basis on which to hypothesize whether an UBRD will render an effective treatment. The compilation of new and existing bird frequency perception information into a single source would be useful for future bird/ultrasonic research efforts.

The need to find an ultimately effective, affordable, easy

to use and easy to maintain bird repelling method makes future research into possible bird control solutions a necessity. Effective bird control methods need to be capable of fulfilling the needs of the many possible applications: Aircraft, airfields, farmlands, buildings, hangars, docks, ships, signs, or any other locations where roosting or flying birds may cause problems.

REFERENCES

Beuter, K. J. and R. Weiss. 1986. Properties of the auditory systems in birds and the effectiveness of acoustic scaring signals. Meet. Bird Strike Comm. Eur. 8:60-73.

Blitz, J. 1967. The properties of ultrasound waves. Pages 1-26 *in* Brown, B. and D. Gordon, eds. Ultrasound techniques in biology and medicine. Charles C. Thomas Publisher, Springfield, Illinois.

Bomford, M. 1990. Ineffectiveness of a sonic device for deterring starlings. Wildl. Soc. Bull. 18:151-156.

Bomford, M. and P. H. O'Brien. 1990. Sonic deterrents in animal damage control: a review of device tests and effectiveness. Wildl. Soc. Bull. 18:411-422.

Brand, A. R. and P. P. Kellogg. 1939. Auditory responses of starlings, english sparrows, and domestic pigeons. Wilson Bulletin 51(1):38-41.

Cohen, S. M., W. C. Stebbins, and D. B. Moody. 1978. Auditory thresholds of the blue jay. Auk 95:563-568.

Dooling, R. J. 1980. Behavior and psychophysics of hearing in birds. Pages 261-288 *in* Comparative studies of hearing in vertebrates. Springer-Verlag, New York.

Dooling, R. J. 1982. Auditory perception in birds. Pages 95-130 *in* Kroodsma, D. E. and E. H. Miller, eds. Acoustic communication in birds, Vol. 1. Academic Press, New York.

Dooling, R. J., and J. C. Saunders. 1975. Hearing in the parakeet (*Melopsittacus undulatus*): absolute thresholds, critical ratios, frequency differentiation limens, and vocalizations. J. Comp. and Physiol. Psych. 88(1):1-20.

Dooling, R. J., and M. H. Searcy. 1985. Nonsimultaneous auditory masking in the budgerigar (*Melopsittacus undulatus*). J. Comp. Psych. 99(2):226-230.

Dooling, R. J., R. J. Mulligan, and J. D. Miller. 1971. Auditory sensitivity and song spectrum of the common canary (*Serinus canarius*). J. Acoust. Soc. Am. 50:700-709.

Dooling, R. J., S. Peters, and M. H. Searcy. 1979. Auditory sensitivity and vocalizations of the field sparrow (*Spizella pusilla*). Bull. Psychonomic Soc. 14:106-108.

Dooling, R. J., S. R. Zoloth, and J. R. Baylis. 1978. Auditory sensitivity, equal loudness, temporal resolving power and vocalizations in the house finch (*Carpodacus mexicanus*). J. Comp. Physiol. Psych. 92:867-876.

Dubco, T. 1984. Shriek devices test tough courthouse pigeons. The Miami News (12 Nov.).

Dugger, C. W. 1984. Noise routs courthouse pigeons. The Miami

Herald (15 Nov.).

Fitzwater, W. D. 1970. Sonic systems for controlling bird depredations. Proc. 5th Bird Cont. Sem. 5:110-119.

Frings, H. and B. Cook. 1964. The upper frequency limits of hearing in the European starling. Condor 66:56-60.

Gordon, D. 1967a. Biological effects below cavitation level. Pages 154-158 *in* Brown, B. and D. Gordon, eds. Ultrasound techniques in biology and medicine. Charles C. Thomas Publisher, Springfield, Illinois.

Gordon, D. 1967b. Mutations and ultrasound. Pages 220-246 *in* Brown, B. and D. Gordon, eds. Ultrasound techniques in biology and medicine. Charles C. Thomas Publisher, Springfield, Illinois.

Granit, O. 1941. Beitrage zur Kenntnis des Gehörsinnes der Vogel. Ornis Fennica 18:49-71.

Greenewalt, C. H. 1968. Bird song: acoustics and physiology. Smithsonian Institution Press, Washington, D. C.

Griffiths, R. E. 1987. Efficacy testing of an ultrasonic bird repeller. Pages 53-63 *in* S. A. Schumake and R. W. Bullard, eds. Vertebrate pest control and management materials: 5th volume. ASTM Spec. Tech. Publ. 974, Philadelphia, Pa.

Harrison, J. B. and L. Furumoto. 1971. Pigeon audiograms: comparison of evoked potentials and behavioral thresholds in individual birds. J. Aud. Res. 11:33-42.

Heinz, R. D., J. M. Sinnott, and M. B. Sachs. 1977. Auditory sensitivity of the red-winged blackbird (*Agelaius phoeniceus*) and brown-headed cowbird (*Molothrus ater*). J. Comp. Physiol. Psych. 91:1365-1376.

Heise, G. A. 1953. Auditory thresholds in the pigeon. Am. J. Psychol. 66:1-19.

Kerns, J. D. 1985. Evaluation of the effectiveness of the "Ultrason ET" ultrasonic device as a means of cliff swallow control. Natural Resources Report No. 85-2. Fort Wainwright, Alaska.

Knecht, S. 1940. Über den Gehörsinn und die Musikalitat der Vogel. Zeitschr. vergl. Physiol. 27:169-232.

Konishi, M. 1973. How the barn owl tracks its prey. Am. Sci. 61:414-424.

Kreithen, M. L. and D. B. Quine. 1979. Infrasound detection by the homing pigeon: a behavioral audiogram. J. Comp. Physiol. 129:1-4.

Kuethe, A. M. and C. Y. Chow. 1986. Foundations of aerodynamics/bases of aerodynamic design, 4th edition. John Wiley & Sons, New York. 555 pp.

Maiorana, V. A. and W. M. Schleidt. 1972. The auditory sensitivity of the turkey. J. Aud. Res. 12:203-207.

Martin, L. R. and P. C. Martin. 1984. Research indicates propane cannons can move birds. Pest Control 52(4):52.

Meyer, D. B. 1986. The avian ear and hearing. Pages 48-59 *in* P. D. Sturkie, ed. Avian physiology: 4th edition. Springer-Verlag, New York.

Meylan, A. 1978. Granivorous birds in sunflower crops. Proc. Vertbr. Pest Conf. 8:73-77.

Pumphrey, R. J. 1961. Sensory organs: hearing. Pages 69-86 *in*

Marshall, A. J. ed. Biology and comparative anatomy of birds. Academic Press, New York.

Quine, D. B. and M. L. Kreithen. 1981. Frequency shift discrimination: can homing pigeons locate infrasounds by Doppler shifts? J. Comp. Physiol. 141:153-155.

Schwartzkopff, J. 1949. Über Sitz und Leistung von Gehör und Vibrationssinn bei Vögeln. Zeitschr. vergl. Physiol. 31:527-608.

Schwartzkopff, J. 1955a. On the hearing of birds. Auk 72:340-347.

Schwartzkopff, J. 1955b. Schallsinnesorgan bei Vögeln. *In* Acta XI congressus internationalis ornithologici. Berhauser Verlag, Basel and Stuttgart.

Schwartzkopff, J. 1968. Structure and function of the ear and the auditory brain areas in birds. Pages 41-59 *in* DeReuck, A. V. S. and J. Knight, eds. Hearing mechanisms in vertebrates. Little, Brown, Boston, Massachusetts.

Schwartzkopff, J. 1973. Mechanoreception. *In* Farner, D. S., J. R. King, and K. C. Parkes, eds. Avian biology, Vol. 3. Academic Press, New York.

Spear, P. J. 1966. Bird control methods and devices; comments of the National Pest Control Association. Proc. Bird Control Semin. 3:134-146.

Stebbins, W. C. 1970. Studies of hearing and hearing loss in the monkey. Pages 41-66 *in* Stebbins, W. C., ed. Animal psychophysics: the design and conduct of sensory experiments. Appleton, Century, Crofts, New York.

Summers-Smith, D. 1963. The house sparrow. Collins, London. 251 pp.

Thiessen, G. J., E. A. G. Shaw, R. D. Harris, J. B. Gollop, and H. R. Webster. 1957. Acoustic irritation threshold of peking ducks and other domestic and wild fowls. J. Acoust. Soc. Am. 29:1301.

Theissen, G. J. and E. A. G. Shaw. 1957. Acoustic irritation threshold of ringbilled gulls. J. Acoust. Soc. Am. 29:1307.

Thorpe, W. H. 1961. Bird song: the biology of vocal communication and expression in birds. Cambridge monographs in experimental biology, No. 12. Cambridge University Press, London and New York.

Trainer, J. E. 1946. The auditory acuity of certain birds. Ph. D. Thesis, Cornell Univ., Ithaca, NY.

Wassiljew, P. 1933. Über das Unterscheidungsvermögen der Vogel für die höhen Tone. Zeitschr. vergl. Physiol. 19:424-438.

Welty, C. W. and L. Baptista. 1988. The life of birds, 4th ed. Saunders College Publishing, New York. 581 pp.

Wever, E. G. and C. W. Bray. 1936. Hearing in the pigeon as studied by the electrical responses of the middle ear. J. Comp. Psych. 22:353-363.

Woronecki, P. P. 1988. Effect of ultrasonic, visual, and sonic devices on pigeon numbers devices on pigeon numbers in a vacant building. Proc. Vertebr. Pest Conf. 13:266-272.

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Low-Level Airspace Bird Strike Hazard Evaluation and Using a GIS to Integrate Bird Population Dynamics Into an Aircraft Bird Avoidance Model

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ABSTRACT:

Twenty-eight percent of all USAF bird strikes occurred during low-level flight operations between 1987 and 1991. These strikes resulted in more than $250 million in damage, the destruction of four aircraft, and five aircrew fatalities. Low-level airspace evaluation once focused only on the Bird Avoidance Model (BAM), which is a useful tool for estimating waterfowl hazards. However, additional bird species not modelled by the BAM, such as raptors, gulls, cranes, and pelicans also pose significant hazards to aircraft operations. Hazards associated with these species are being examined separately using known bird population and migration dynamics. To reduce hazardous and costly bird strikes to aircraft, the USAF BASH Team is updating the BAM. The new BAM will calculate the relative risk of a bird strike by integrating biological and geographical data into a Geographic Information System (GIS). The GIS is allowing detailed analyses of robust databases, including the North American Breeding Bird Survey (BBS), Bird Banding Recovery, Christmas Bird Count (CBC), Hawk Migration Association of North America (HMANA), and Refuge databases which have helped verify bird distribution and abundance in the BAM. The USAF BASH Team will continue to enhance the BAM through the future addition of weather components and the integration of bird recognition data provided by the Next Generation Weather Radar (NEXRAD). NEXRAD will provide a near real-time bird avoidance capability for low-level aircraft operations.

Low-Level Airspace Bird Strike Hazard Evaluation and Using of GIS to Integrate Bird Population Dynamics Into an Aircraft Bird Avoidance Model

BACKGROUND: The United States Air Force (USAF) is reports more than 3,000 bird aircraft collisions each year. Approximately 28% of USAF bird strikes from 1987 to 1991 occurred during the low-level and range phases of flight. These strikes caused a disproportionate amount of damage, due to higher aircraft operating speeds, and resulted in the destruction of four aircraft, five aircrew fatalities, and greater than $250 million in damage. In the early 1980's, the Bird Aircraft Strike Hazard (BASH) Team developed a predictive risk model to identify areas and times associated with high bird strike risk. The Bird Avoidance Model (BAM) estimates the probability of a bird strike along a low-level training route by distributing a density of birds into a volume of space and sweeping the frontal surface area of an aircraft through that space. The BAM has been a useful tool for estimating waterfowl (ducks, geese, and swans) hazards, but other birds considered hazardous to military aircraft operations were not incorporated into the model. Birds such as raptors (birds of prey), gulls, cranes, and pelicans are evaluated separately using known population and migration dynamics, however these data for many species remain incomplete.

CURRENT RESEARCH: The BASH Team has recognized the necessity of incorporating these potentially hazardous bird species as well as terrain features associated with increased bird activity into a new Bird Avoidance Model. The current BAM program lacks the flexibility to add species, update databases of dynamic biological systems, and incorporate geophysical data. The use of Geographic Information System (GIS) technology offers the ideal solution for integrating these spatial data. Data to be incorporated into the model will include bird species' weights, flock densities, a relative aircraft damage factor, and species' behavioral differences. The temporal aspects of the hazards, including time of year (seasonal variation) and time of day (diurnal variation) and associated altitude components will be included in the risk assessment. The BAM output, provided to military flight and mission planners, will include a graphical depiction of bird hazards and a text file with recommendations for aircraft operations in the vicinity of the hazard. Modelling efforts for the continental United States are currently underway using Geographic Resource Analysis Support System (GRASS). GRASS is a public domain GIS developed by the U.S. Army Corps of Engineers Construction Engineering Research Lab (USACERL). This raster-based GIS, run on a UNIX-based operating system, is ideally suited to analyze biological distribution data and provides the flexibility to add species and calculate risk based on selected criteria.

Geographically referenced population and migration dynamics for waterbirds, raptors, cranes, pelicans, gulls, and blackbirds are being collected from state and federal agencies and are entered into a Dbase III+ file. The GRASS GIS has allowed easy analysis of robust databases such as The Hawk Migration Association of North America (HMANA), North American Breeding Bird Survey (BBS), Christmas Bird Count (CBC) and Bird

Banding Recovery to aid in the verification of bird distributions and abundance in th BAM. The expanded BAM is scheduled for completion in September 1993.

FUTURE RESEARCH: The BAM can be supported by bird movement and altitud data and ultimately weather components supplied by the Next Generation Weather Radar (NEXRAD) system, once it becomes operational. Recognition algorithms for waterfowl, gull, and blackbirds for NEXRAD have been developed. The NEXRAD system will provide coverage for most of the United States and a large section of Europe, and will furnish a near real-time bird avoidance capability for low-level milit aircraft operations.

The US Air Force experiences a significantly higher bird strike rate during low-level operations outside the United States. In Europe, low-level bird advisories are issued a result of personal observations and observations of air defense radars located in Belgium, The Netherlands, and Germany. The integration of these advisories along geophysical and biological databases, with a predictive model based on GRASS will significantly improve flight safety. The BASH Team hopes to begin collecting data f this effort in Fall of 1992. Deployments into regions such as the middle east, with extremely hazardous bird migrations, emphasized the need for a global-scale modelli effort. The BASH Team is searching for global migration path information and establishing contacts with European and global GRASS users.

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EVALUATION OF SHOTGUN SHOOTING TO REDUCE AIRCRAFT STRIKES BY LAUGHING GULLS AT JOHN F. KENNEDY INTERNATIONAL AIRPORT, 1991

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Abstract

The collision of birds with aircraft is a serious problem at John F. Kennedy Internatio Airport (JFKIA), New York City. Laughing Gulls *(Larus articilla)* from an 8,000-nest colony next to the airport in Jamaica Bay on National Park Service (NPS) property, ar the most frequently struck bird, averaging 169 birds struck (by 156 aircraft) per year from 1988 to 1990. An experimental program was undertaken in 1991 in which 2 to 5 people stationed on airport boundaries shot gulls with shotguns on 62 days from 20 M to 8 August. In all, 14,191 Laughing Gulls and 695 other gulls [(herring - *Larus argentatus*, Great Black-backed - *Larus marinus*, and Ring-billed - *Larus delawarensis*)] were killed in 896 person-hours of shooting. Over 93 percent of the Laughing Gulls killed were adults and 95 percent of these had brood patches, indicating they were nesting birds. Bands recovered from shot gulls indicated many of the adult gulls were hatched in colonies along the New Jersey coast at least 100 km away. The number of Laughing Gull strikes with aircraft was reduced by 60 percent compared with the mea level for the previous three years. The reduction in strikes appeared more closely related to a direct reduction in the population rather than to a change in flight patter of gulls caused by shooting. The shooting program will continue in 1992. A detailed report of the shooting experiment will be prepared after the work in 1992 is complete The long term solution will be to relocate the colony from Jamaica Bay and JFKIA.

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Bird Strikes to U.S. Air Force Aircraft 1987 - 1991

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Each year the U.S. Air Force (USAF) suffers significant aircraft damage from bird strikes. Between 1987 and 1991 USAF activities worldwide reported over 14,000 bird strikes to the USAF Bird Aircraft Strike Hazard (BASH) Team. During this period, aircraft were destroyed, one suffered damage in excess of one million U.S. dollars, an five aircrew members were fatally injured, all due to aircraft collisions with birds. Th average annual cost to the USAF is in excess of 59 million dollars (U.S.) not to ment the cost in human lives and agonizing suffering. The following are summaries of all Class A mishaps (mishaps that resulted in the destruction of the aircraft, involved los: life, or sustained damage in excess of $1,000,000) due to collisions with birds for the period of 1987 through 1991.

o In May 1987, an F-4E operating over the Bardenas-Reales bombing range struck a 20 pound Griffon Vulture (*Gyps fulvus*) during high speed low-level flight. T bird penetrated the windscreen of the aircraft, killing the pilot. The weapons system operator was subsequently killed when the aircraft impacted the ground seconds later The aircraft was destroyed with cost estimates exceeding $17,000,000.

o In September 1987, a B-1B operating on a high speed low-level training rou in LaJunta, Colorado struck a 15 pound American White Pelican (*Pelecanus erythrorhynchos*) while traveling at 500 knots and 600 feet above the ground. Three c members ejected safely after control of the aircraft was lost. The remaining three cre members were killed when the aircraft crashed into the ground. The aircraft was destroyed with cost estimates exceeding $215,000,000.

o Later in December 1987, an E-4B (modified Boeing 747) departed Offutt A Nebraska on a routine mission. During climb-out the aircraft struck numerous Snow Geese (*Chen caerulescens*) weighing an average of 5.5 pounds each. The aircraft was immediately and successfully recovered to the base. No injuries or fatalities were attributed to this mishap. Damage to the aircraft exceeded 1.5 million dollars.

o During 1988 no Class A mishaps due to bird strikes were reported. Howev during early January 1989 an F-16A operating over the Avon Park Bombing Range ir Florida was lost after it struck a 4.5 pound Turkey Vulture (*Carthartes aura*). The aircraft was egressing the target when the collision occurred. The Turkey Vulture str the aircraft and penetrated the canopy. The pilot was temporarily and partially paralyzed by the bird and aircraft debris. The pilot successfully ejected. His injuries

were minor and he was returned to flight status. The aircraft was totally destroyed at a cost estimate of $10,000,000.

o Only days after the preceding mishap, an F-16C at Shaw AFB, South Carolina was on its takeoff roll when it struck several starlings. The pilot initiated an unsuccessful high-speed abort resulting in the loss of the aircraft. The pilot escaped uninjured, however, the aircraft was destroyed. Cost estimates for this mishap exceed $10,000,000.

o The next Class A mishap resulting from a bird strike occurred more than a year later when an F-16A from the Ft Smith Air National Guard in Arkansas ingested a 4.5 pound Turkey Vulture (*Carthartes aura*) while on a low-level training mission. The pilot ejected successfully, but the aircraft was destroyed at an estimated cost of $9,000,000.

These are the most graphic examples of the devastating effects birds had on our aircraft during the past five years. Although many of the most damaging bird strikes occurred during high speed low-level flight, aircraft can be severely damaged and even destroyed during any phase of flight. Even with the perception of a reduced military threat in Europe, aircrews must continue to train to meet contingencies worldwide. High speed low-level flight continues to offer pilots the elements of evasion and of surprise, but it also places them in the same airspace where most bird activity occurs. The USAF BASH Team is aggressively increasing efforts to identify bird hazards in low-level airspace. An enhanced Bird Avoidance Model (BAM) for North America is under development. Reducing bird hazards on and around USAF installations requires continued education and training for base personnel. Since 1987, a decrease in the number of Class A mishaps from bird strikes has been observed. The BASH Team continues to conduct instruction at the Flight Safety Officers' School, University of Southern California, Norton AFB, California and the Flight Safety NCO's Course, Lowry AFB, Colorado. These efforts have advanced the awareness of the BASH potential Air Force wide and have improved the BASH programs at USAF installations worldwide.

The following is a summary of bird strike data reported throughout the Air Force for the period beginning January 1987 through June 1991. Due to a change in reporting periods, the data for the last six months of 1991 will not be available until April 1992. No statistical analysis is offered here, but this information is useful to identify trends and used to focus future BASH Team efforts.

Aircraft Involved in Bird Strikes

For the period of 1987 through 1991 virtually every aircraft in the USAF inventory reported bird strikes, some in greater numbers and frequency than others. Figure 1 shows the aircraft type that reported the most strikes. Cargo and fighter/attack aircraft continue to report bird strikes in the greatest number and frequency. With increased emphasis on low-level flight for almost every weapons system, we expect the numbers to continue to climb barring no intervention.

Impact Location

The frontal surface area of an aircraft, duration of exposure, and the type of mission is directly related to the frequency of reported bird strikes for hours flown. Figure 2 shows the percentage of total bird strikes by impact location.

Again, transparencies and engines continue to lead the list. As a result of data provided by the BASH Team the transparencies to the F-15E have been improved to withstand heavier birds at high airspeeds. However, this has not eliminated the hazards to the aircrew while operating low-level. Shortly after the improved windscreen was installed on the F-15E, a crew operating over Dare County Range in North Carolina sustained a bird strike that shattered the windscreen but did not penetrate the cockpit.

Bird Strikes by Altitude

The distribution of bird strikes by altitude remains typically constant from year to year. At almost any altitude birds may be encountered. The highest strike recorded was at 37,000 feet. Most birds fly much closer to the surface. Over 95 percent of all reported strikes are reported at or below 3,000 feet above ground level (AGL). Figure 3 shows bird strikes by altitude. Strike rates drop dramatically as altitude increases. Since most bird activity occurs close to the ground, this is to be expected. Any increase in the altitude where an aircraft operates significantly reduces the potential for a bird strike except during migratory activities. The BASH Team continues to stress these observations when interfacing with pilots and mission schedulers. During migratory seasons, it is important for aircrew to be cognizant of migratory corridors and associated behavior of bird species which may be encountered.

Times When Bird Strikes Occur

At most anytime of the day or night a bird strike may occur. Typically, though, bird strikes are more common at specific times of the day. The vast majority of USAF flight operations take place during the daylight hours and this accounts for the number of reported bird strikes. Figure 4 shows reported bird strikes by time of day. Although the numbers of strikes reported during dawn and dusk are low, these times are particularly hazardous since birds are extremely active during dawn and dusk. In some instances, USAF installations have adjusted departures and recoveries to avoid bird hazards associated with dusk and dawn. Migratory activity accounts for most strikes reported at night during the spring and fall.

Figure 5 depicts bird strikes by month. As expected, the numbers increase during the migratory months. During August, September, and October the frequency of reported bird strikes is the greatest. This corresponds with their movement south following the summer breeding season.

Bird Strike by Phase of Flight

Bird strikes are reported in all phases of flight. Bird strikes on and around the airfield account for more than 60 percent of all reported strikes (Figure 6). Aircraft operating in and around the airfield are traveling at relatively slow airspeeds. The damage sustained for aerodrome reported strikes is normally minimal due to the slow aircraft speeds.

Slightly over 25 percent of the reported strikes occur during range and low-level operations, however these strikes are the most severe and costly. Two thirds of the Class A mishaps since 1987 occurred during range and low-level operations and account for all the fatalities for this period. Careful airspace planning, development, and scheduling help to reduce bird strikes during operations in this environment. The BASH Team continues to invests efforts and money to reduce the low-level strike potential. Expanding the BAM is 50 percent complete. Completion is projected for late 1993. The current model includes waterfowl and some raptor hazards for the continental United States. The expanded model will include additional raptor species, gulls, pelicans, cranes, and other hazardous flocking species. Units using the current BAM have observed reduced numbers of strikes.

Dover AFB, Delaware has successfully employed radar to identify Snow Geese movements between late fall and early spring. In addition to this current use of radar, the Next Generation Weather Radar (NEXRAD) will discriminate bird movement from weather phenomena. NEXRAD is a tri-agency program between the Departments of Commerce, Transportation, and Defense. Once fully deployed NEXRAD, a network of state-of-the-art doppler weather radars, will provide improved detection of severe and economically significant weather events over the continental United States and portions of the Pacific and Europe. Results indicate this doppler weather radar can detect bird movements as well as provide altitude information. This information may provide bird hazard information during mission planning and should enhance avoidance during flight. The BASH Team sponsored the development of a bird recognition algorithm for inclusion in this system. During the next phase the BASH Team will explore the development of a bird warning system. NEXRAD will provide "near real-time" information. The need for a real time bird warning system still exists. We continue to explore technologies to fill this void.

Birds Identified in Strikes

A wide range of bird species have been identified following collisions with USAF aircraft. Units forward post-strike remains to the BASH Team when they cannot be identified locally to the genus and species level. Most of the remains received for identification are forwarded to Ms. Roxie Laybourne for microscopic analysis. The birds identified indicate raptors, particularly Turkey Vultures, are responsible for a majority of the most damage sustained. Table 1 lists the birds most commonly identified birds in aircraft mishaps without regard to damage or cost.

Summary

The Air Force continues to suffer fatalities, injuries, and lost and damaged aircraft. 19 remains the most costly year on record in terms of lives and damage. Since 1987 the number of Class A mishaps has declined and no fatalities attributable to bird strikes have been reported. Nonetheless, much remains to be accomplished to reduce the BASH potential during all phases of flight. With efforts focused on the expanded BAI low-level route evaluation, NEXRAD, and emerging technologies we can expect more success in conserving USAF resources and aircrew lives. Only through cooperation car these goals be realized. The USAF BASH Team remains committed to this challenge and will work to explore and expand efforts to this end.

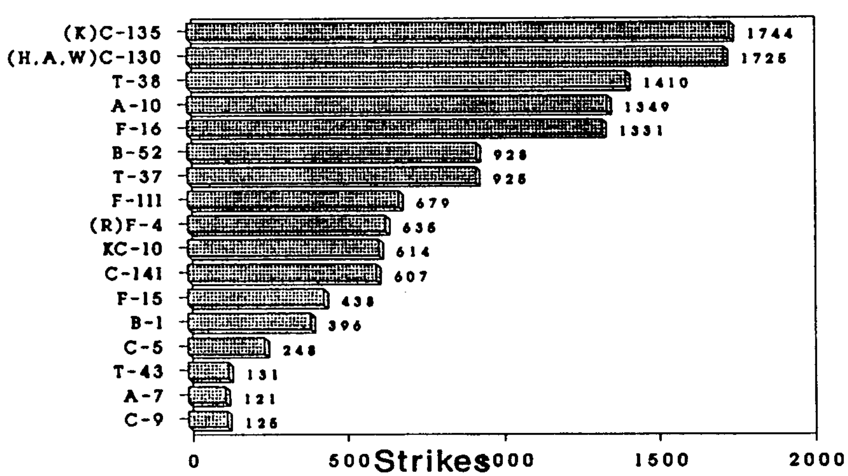


Figure 1. Strikes by Aircraft Type

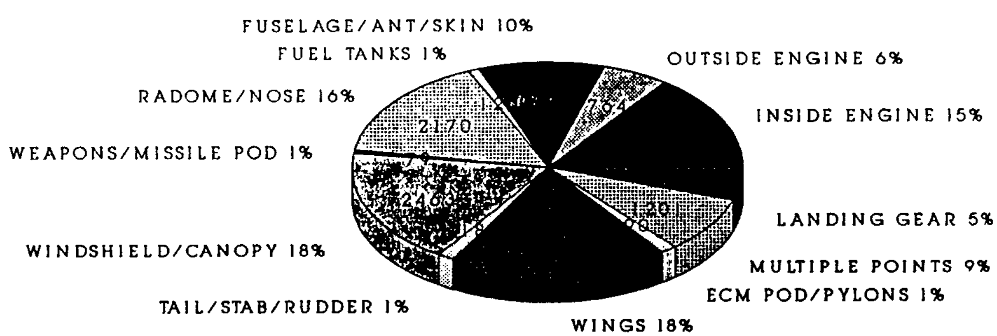


Figure 2. Strikes by Impact Point

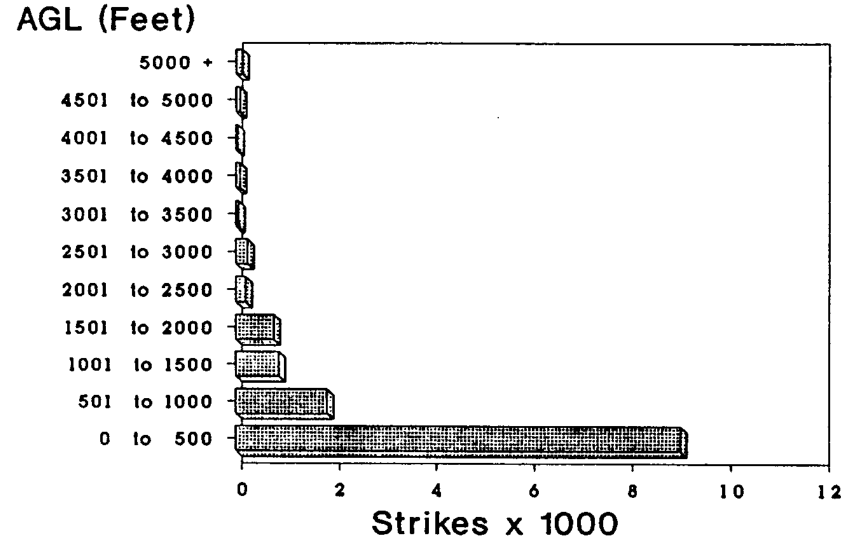


Figure 3. Strikes by Altitude

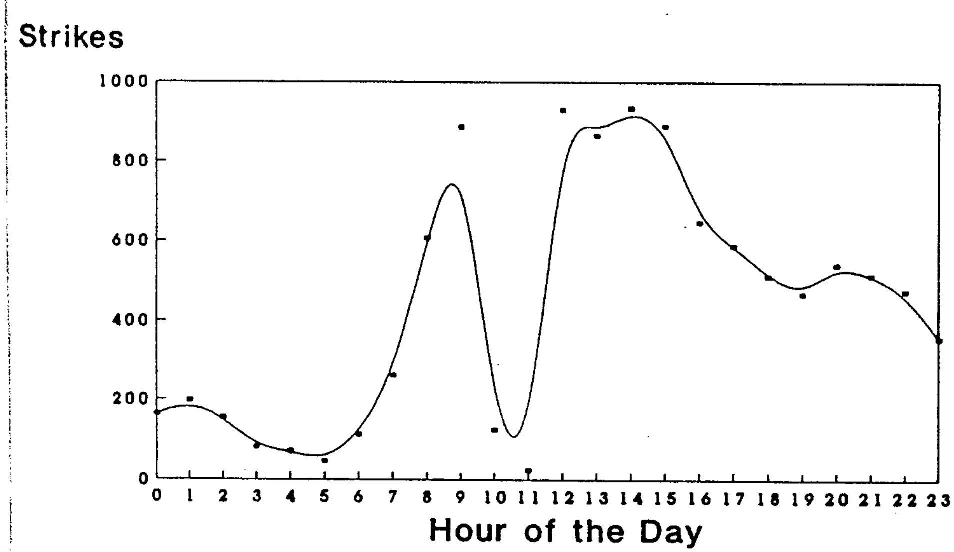


Figure 4. Strikes by Hour

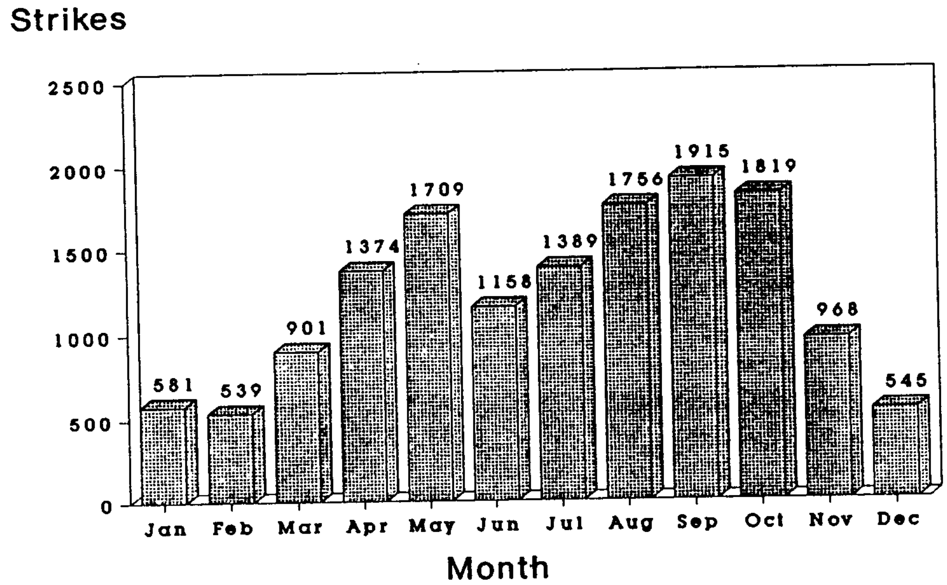


Figure 5. Strikes by Month

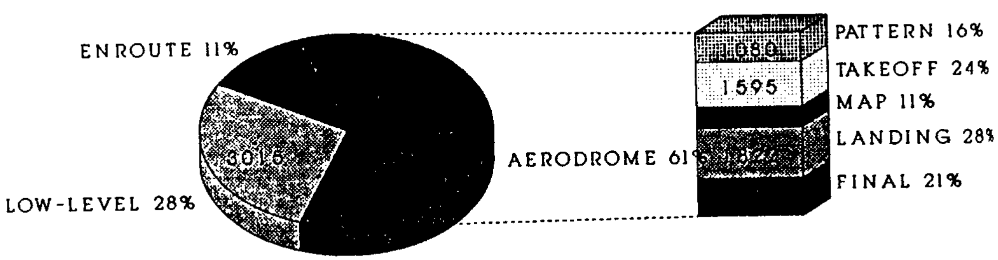


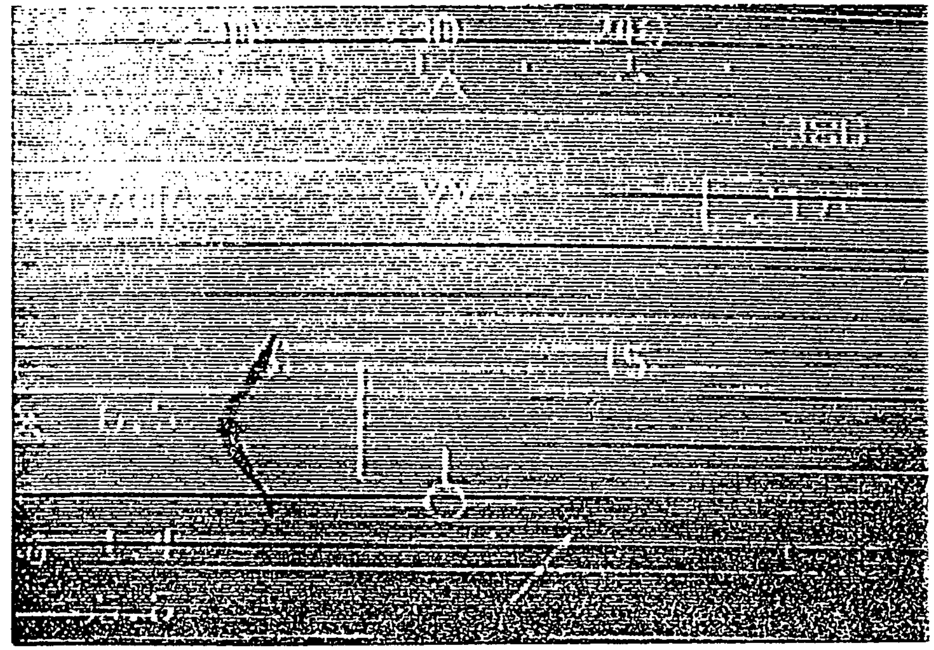
Figure 6. Strikes by Phase of Flight

SPARROW	434
HORNED LARK	124
TURKEY VULTURE	122
GULL	114
BLACKBIRD	64
MEADOWLARK	59
RED-TAILED HAWK	58
BLACK VULTURE	57
BARN SWALLOW	53
MOURNING DOVE	50

Table 1. Birds Identified in Strikes

wp 43

VULTURES IN SPAIN



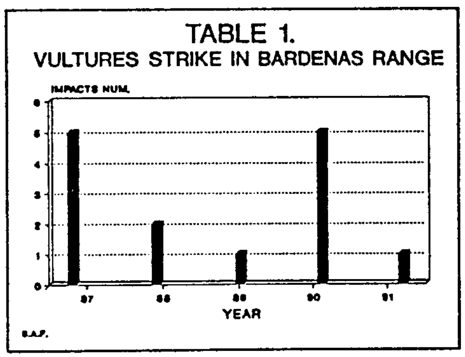
S.A.F.
cap. Jorge Clavero Mañueco
ZARAGOZA AIR BASE

1 VULTURES IN SPAIN.-

The Spanish population of Griffon Vultures (Gyps fulvus) is 80% of the European population. About 25,000 are spread throughout several parts of Spain.

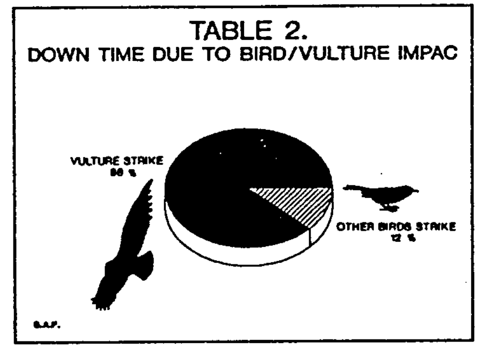
Characteristics of large size, heavy weight (8 Kg), long distance traveling and they fly in big flocks, make them a constant danger for Low Level Navigation.

Statistics support this affirmation. In the Bardenas Range -Navarra- the average of strikes by vultures per year is 2.8 . TABLE 1.



The importance of these accidents is greater if we consider that at this Range, three pilots have lost their lives, in recent years.

TABLE 2. SHOWS DOWN TIME DUE TO BIRD/VULTUR IMPACT



STATUS AND DISTRIBUTION.-

The II National Survey of the Griffon Vulture shows the increase of the population between 1979 and 1989 is estimated 90%.

The distribution is very irregular. Absent in both plateaus, North-West mountains, Guadalquivir basin and East Coas The highest densities are found in the Iberic Massif, centr and western Pirenees, eastern cantabric mountains, Sierra Beti and Mountains of Toledo.

FIG 1. The province with the highest population is Navarr with 45 nesting colonies -about 2200 birds-.

The increase in population has occurred in the same coloni as 10 years ago, especially those which had more than 30 breedi

pairs.

This rapid population increase is attributed to less persecution, less poisoning and more abundant food resources

The number of breeding ranches has grown 20% in the last 10 years.

Poisoning is the main factor of mortality. The breeding rates have been studied in 53 colonies, including 1074 pairs. Breeding success is 0.76. Applying those results to the total population, we discover that each year 3500 new vultures will fly in Spain.....

But, what will limit the maximum population ? Probably not enough food resources will be the first cause to stop the number of growing birds. Isolated colonies in the Adriatic islands show us the relation between vultures and number of animals from which it feeds (goats, sheeps, etc) is 1/583. In Spain it is lower; 1/871. This means vultures will increase 32% more, reaching a total number of 30.000 birds, to many vultures to fly safely in those areas.

ACTIVITY.-

Altitude of Flight over ground: Becasue of the body weight of about 8 Kg the Gyps F. they prefer to soar when flying. Therefore, they are dependant on thermal upcurrents or anabatic wind near cliffs, hills or mountains. Normally, anabatic winds

extend 0-500 meters over the top of a barrier. Vultures fly with thermal upcurrents, which take them up untill they reach the cloudbase. This depends on the altitude of the condensation level, which fixes the cloud base.

Flying Activity: The time of activity in the morning will be about 1-3 hours after sunrise. Even in Stratus clouds and fog there might be good thermals because of unstable conditions. Reduced flying activity is in early morning and in late evening (In summer they might fly till 22:00 hrs) The general pattern looks like this: Vultures take off about 07:00 - 11:00 in the morning, return about 12:00 - 15:00 in the midday, take off again and return around 17:00 - 22:00 in the evening. The seasonal effects, which influence activity patterns correlate with the lengh of day light.

Greater flying activity in correlation with wind velocity: With wind velocities of 55-60 km vultures don't usually leave their colony. But, the motivation to fly will depend on the need to search for food.

Foraging Areas: They do not have special corridors in which to fly, and they don't have a defined home range area. They do not fly only in one direction. They extend over a large area and maintain visual contact with neighbouring flying vultures. The flying radius is about 25 km during the reproductive period till the young vultures learn to fly. For vultures without chicks the radius might be about 50 km.

Another reason to fly in one direction, is to change the habitat area from summer to winter. In winter time the areas of the northern colonies are covered with snow. This makes adult,

sub-adult and juveniles move to more southern districts without snow. The oriented flight takes place when some of the young vultures fly SSW to regions in south Spain. The displacement takes place in October - November. This is the period when there are more vultures in the area of Zaragoza.

Soaring parameterss:

Glide angle ratio	15:1
Flying speed when cross country	50-65 km/h
Slow search flying	15 km/h
Fast flying	100-150 km/h

SOLUTIONS.-

First of all, it would be wonderfull to maintain a fixed number of birds, but this would be very difficult to do in a society more sensitive to Ecological concerns than Defense affairs.

To study, and to mark off each colony activity area. We could limit the range of the vultures by placing dead animals (carcasses) nearer the colonies.

Apply The Spanish Epizootias Law -1953- which states that everybody should burry their own dead animals.

Don't fly in active vulture areas. Establish a Danger Color Code, for areas, corridors, airfields, ranges etc, where vulture presence is frequent.

AVOID.-

To avoid collision it would be "better" to fly before 07:00 in the morning or after 21:00 in the evening and not during the times, when there are activity peaks of the vultures. There will be limited Vulture activity during thunderstorms, when there is no thermal upcurrent and adiabatic upcurrent or if there is very strong wind. Also it is unlikely that there are vultures flying over snowy areas in wintertime.

Controlers and/or pilots information will establish the Color Code.

Example:

ORANGE...........birds presence...........Danger
RED..............moderate density.........High Danger
BLACK............high density...... .....Closed to Traffic

It is difficult to improve aeroplanes against vulture strikes.
There are no airplane materials strong enough to support an impact of 8 Kgrm. at 500 kts.

Pilots have to watch for vultures flying in thermal columns and in places with anabatic winds. If impossible to avoid danger areas, pass through it perpendicularly. When the pilot observes there are Vultures he should follow the following procedures:

-If there is enough time to react.

*Pull up immediately

*Inform other pilots (controler) in the vecintiy

*Leave that area immediately.

-If there is not enough time or critical flight conditions.

*Do not react, just protect the face.

SUMMARY.-

Vultures density in Spain represent a big problem to Low Level Flying

Vulture strikes represent 88% of aircrafts maintenance recovery time and 95% of aircraft damage.

To decrease these bird strikes it would be necessary to mark off as much as possible the bird activity areas. Paint a precise map of those areas and don't overfly them in daylight hours at low level.

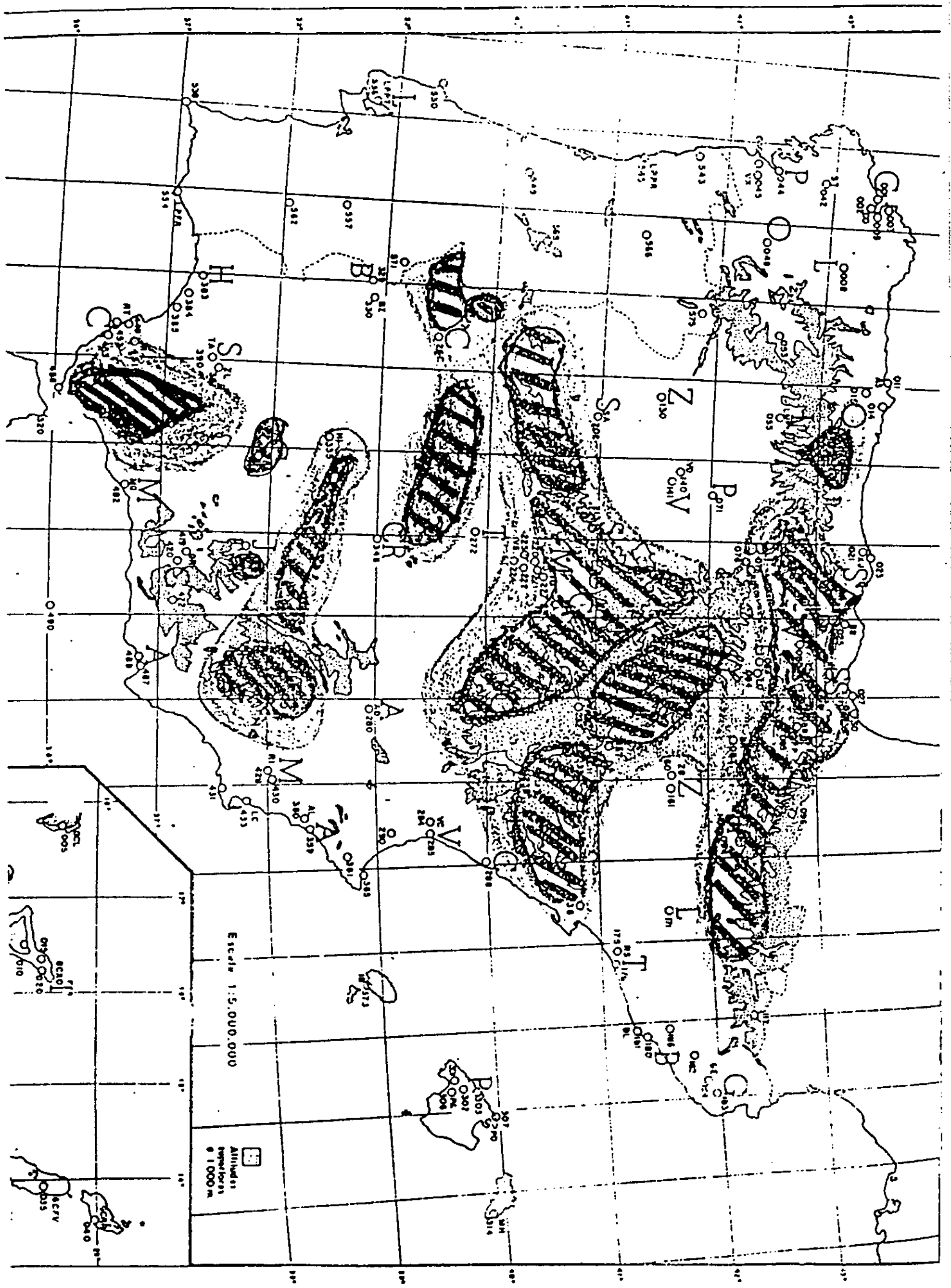
Use a Birds Danger Color Code.

Apply pilots bird strike procedures, and inform other pilots/controlers in the area.

In a word avoid coinciding in the same space/hour

with the Vultures.

ZARAGOZA AIR BASE MARCH 1992.



SUBSITUTE BIRD
OBJECTIVES AND CONSTRAINTS

IPA Jean-Pierre DEVAUX
DGA/CEPr
SACLAY
FRANCE

Abstract

Wild and farming bird use for bird strike resistance testing is no longer allowable both for philosophical and technical reasons. Bird life must be preserve and it seems that animal use for technical experiment will no more be acceptable to non concerned people. Technically speaking, wild or farming bird use for test representativity reasons is contestable as none of those bird can be representative of real bird strike involved birds. Test repetability, considered as the most important parameter in all qualification test, is not accessible with real birds.

Many problems should be solved before using systematically substitute bird in engine and structure bird strike resistance tests. Substitute bird choice should square with well defined and approved mechanical, aerodynamical and geometrical criteria.

Cooperation between BSCE members can be very useful to Civil Aviation Authorities in such a matter.

CEPr conclusions on the subsitute bird problem are given at the end of the article.

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SUBSTITUTE BIRD OBJECTIVES AND CONSTRAINTS

IPA DEVAUX Jean - Pierre

21 TH BSCE
JERUSALEM

25.03.92 CENTRE D'ESSAIS DES PROPULSEURS

DGA

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SUBSTITUTE BIRD OBJECTIVES AND CONSTRAINTS

SUMMARY

* WHY A SUBSTITUTE BIRD IS NEEDED
  - WILD BIRD PROTECTION
  - TEST REPRESENTATIVITY
* MAIN PROBLEMS TO SOLVE
  - SUBSTITUTE BIRD DEFINITION & DESCRIPTION
  - SUBSTITUTE BIRD CHOICE PROCEDURE
* CEPr CONCLUSIONS

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WHY A SUBSTITUTE BIRD IS NEEDED

416

* WILD BIRDS PROTECTION

* RESPECT OF LIFE

* TEST REPRESENTATIVITY

* CONCLUSIONS

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WHY A SUBSTITUTE BIRD IS NEEDED

417

* WILD BIRDS PROTECTION

  - FARMING BIRDS CHOICE : ALWAYS POSSIBLE (CHICKEN - TURKEY - DUCK)

    ==> BIRD WEIGTH EASY TO ADJUST
    ==> BIRD DELIVERY EASY BOTH IN TERMS OF QUANTITY AND DELAY
    ==> FARMING BIRDS IS THE MOST SENSIBLE SOLUTION ...

    ... BUT : o THEY DON'T FLY !
    o THEY ARE NOT THE SPECIES INVOLVED IN BIRD STRIKES

WHY A SUBSTITUTE BIRD IS NEEDED

* WILD BIRDS PROTECTI

- PROBLEMS RAISED BY FARMING BIRDS USE

==> BIRDS MORPHOLOGY)
) ARE NOT THE SAME
==> WEIGHT DISRIBUTION)

o ENGINE TESTS ARE OFTEN MORE SEVERE THAN NEEDED

o COMPARISONS WITH REAL BIRD STRIKES ARE HAZARDOUS

WILD BIRDS ARE MORE REPRESENTATIVE THAN FARMING BIRDS

CENTRE D'ESSAIS DES PROPULSEURS

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WHY A SUBSTITUTE BIRD IS NEEDED

* WILD BIRDS PROTECTION

- PROBLEMS RAISED BY WILD BIRDS USE :

==> MOST OF THE SPECIES ARE PROTECTED

==> BIRD WEIGHT HARD TO REACH : WEIGHT ADJUSTEMENT OFTEN NEEDED

==> QUANTITY AVAILABLE, DELIVERY DELAY, ETC... ARE HAZARDOUS

==> BIRDS REPRESENTATIVITY(EX : 4 POUNDS HEARING GULL !)

WILD BIRDS IS NOT AN EASY SOLUTION TO DEAL WITH !

CENTRE D'ESSAIS DES PROPULSEURS

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WHY A SUBSTITUTE BIRD IS NEEDED

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* RESPECT OF LIFE

BOTH FARMING BIRDS AND WILD BIRDS ARE LIVING BEING

PEOPLE SENSIBILITY AND TEST REQUIREMENTS ARE BEGINNING TO DIVERGE

BIRDS USE FOR BIRD STRIKE TESTS WILL BE RESTRAINED AND OUTLAWED VERY SOON !

DGA

WHY A SUBSTITUTE BIRD IS NEEDED

421

* TEST REPRESENTATIVITY

o TEST REPETABILITY FROM ONE RIG TO AN OTHER

- NO COMPARATIVE TEST POSSIBLE : TEST COST TOO HEAVY

==> VERY FEW DATA AVAILABLE

==> REPETABILITY IS A BASIC ASSUMPTION !

DGA

CENTRE D'ESSAIS DES PROPULSEURS

WHY A SUBSTITUTE BIRD IS NEEDED

* TEST REPRESENTATIVITY
  - o TEST REPETABILITY FROM ONE RIG TO AN OTHER
    - - MAIN DIFFERENCES
      - ==> BIRD SPECIES CHOSEN

        (AERODYNAMIC CHARACTERISTICS, WEIGHT DISTRIBUTION)
      - ==> TIME SPENT BETWEEN BIRD DEATH AND BIRD USE

        (INCLUDING DEFROZEN TIME)
      - ==> SHOOTING SYSTEM & BIRD BEHAVIOUR DURING GUN ACCELERATION

DGA

CENTRE D'ESSAIS DES PROPULSEURS

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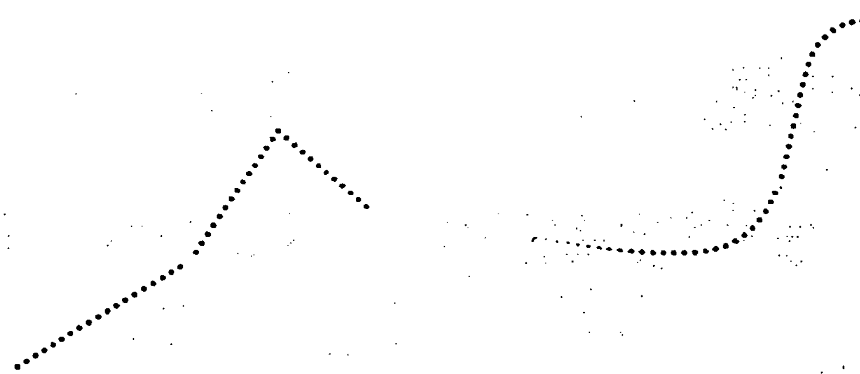
WHY A SUBSTITUTE BIRD IS NEEDED



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CENTRE D'ESSAIS DES PROPULSEURS

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WHY A SUBSTITUTE BIRD IS NEEDED

* TEST REPRESENTATIVITY
  - o TEST REPETABILITY FROM ONE SHOT TO AN OTHER
    - - BIRD WEIGHT DISPERSION
      - ==> WEIGHT ADJUSTEMENTS ARE OFTEN NECESSARY
    - - TWO SOURCES OF BIRD TRAJECTORY DISPERSION
      - ==> BIRD WEIGHT DISTRIBUTION DISPERSION (DENSITY - CENTER OF GRAVITY)
      - ==> BIRD AERODYNAMICAL CHARACTERISTICS

CENTRE D'ESSAIS DES PROPULSEURS

List of participants as per 26 March 1992

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p. 425 - 439
omitted
(List of participants)

Report of the Chairman

Monday, 23 March 1992

Already during the meeting in our Committee in Copenhagen 6 year ago, we were approached by representatives from Israel on the possibility of having a BSCE meeting in the future in Israel, which the Steering Committee gladly accepted. This fact will illustrate that you have to be well in advance of planning for meeting places for meetings such as BSCE. I will not refrain from urging countries which would like to host a BSCE meeting in 1998 or later to contact the Chairman as soon as possible.

Since our meeting two years ago, we have celebrated the 25 years' anniversary of our Committee. The celebration took place in Frankfurt, Germany, almost on the same dates where a few of us met. The celebration included speaches of contratulations from representatives from the Federal German Minister of Traffic, from the German Air Forces, from the Airport of Frankfurt and from the German Committee regarding bird Strikes. I had the pleasure to give a small address in going through the history of our Committee. The German airline Lufthansa in the Airport of Frankfurt took care of our needs to dine and wine and there was a very good press coverage of the event. I take this as an appreciation of the work being done in our committee and on the more social line we had the opportunity to meet former familiar faces from the work of our Committee, such as Dr. Kell and Vital Ferry who both have retired.

After the celebration festivities, the Steering Committee met to work out preparations for this meeting and to discuss other items among which I shall inform you as follows:

1. We discussed the wording of our Terms of Reference, both the Committee as such and the various working groups. The existing Terms of Reference can be found in the Invitation Letter, Working Paper 1, but in Working Paper 2 you will find a proposal for some changes and this will be dealt with later on today during the Plenary meeting.

2. That brings me to the second item on which I would like to give some highlights. We decided to avoid duplication of presentation of working papers to have a Plenary, as you will see from the Invitation Letter, on the first day of our meeting and dealing

with working papers assigned to the Plenary. This leaves us with almost 4 hours in the Plenary today and we hope that we can finish the already prepared working papers in order that on Friday we will mostly have to discuss the reports of the various chairmen and some other items properly presented during the end of the meeting.

3. In order to increase the usefulness of our Index of papers you will have observed that in the Invitation Letter we now ask for what is called "Keywords" to make it easier for the Chairman to find proper places for working papers in the Index. Some working papers are indeed supplied with these new keywords.

4. We have decided to continue stressing the need for advance notice of working papers also to the benefit of the participants to the meeting as you also will have observed from the Invitation Letter which indicates the possibility of more rigorous consequences of not observing the time limits for presentation of papers. For this meeting, however, the Steering Committee has decided to be more overbearing.

5. We decided that the Working Group chairmen should start work in their respective groups in reporting the activities since the last meeting in more details than I shall do in this introductory report.

6. We acknowledged that the distribution of papers to the various working groups or the Plenary should be decided by a Steering Committee meeting and that is the reason why the Steering Committee already met last night to make preparations for the meeting today.

7. As I told you already in Helsinki, it is assumed that participants to the meeting have already studied the working papers, at least the working papers available at the beginning of the meeting. This should have as a consequence that the oral presentation of a working paper could be reduced to a summary of the paper and not take more than say 15 minutes in order to allow time for discussions. We have seen that lecturers also for this meeting have taken good notice of our recommendation that working papers should contain references to Proceedings of earlier meeting to avoid recapitulation of the work done in the past. At this meeting we have till now received 37 working papers compared to 28 working papers at the beginning of the Helsinki meeting.

Papers received after the extended deadline and due to the very efficient management of our host country, this deadline was only a week ago, but do not think that this will be the fact at the next meeting, could be found at the entrance of the meeting place and if you would like to present more working papers to be included in the Proceedings, you should address my secretary, Kirsten Falk Mortensen, who will be responsible for numbering the papers in order that we can avoid the confusion we have had in the past.

I shall now turn to the work performed in the last two years in the various working groups and the first will be the **Aerodrome Working Group** with Heikki Helkamo from Finland as chairman.

At our last meeting, this Group was left with the following recommendations:

1. BSCE members from EEC countries are urged to ask the appropriate authorities to take into account, when dealing with applications for grants, that changes in land use may affect the potential birdstrike problem at a neighbouring aerodrome and that consultation with aviation authorities and aerodrome authorities might be desirable.

2. The BSCE members should draw the attention of the appropriate authorities to the existence of expert systems to integrate bird data, weather data and control methods. These systems will provide critical information for new personnel assigned to bird control and will assist management in scheduling efforts.

I know that the Danish and the Dutch administrations have taken initial steps to ask the appropriate authorities to comply with the first recommendation, and I assume that Heikki Helkamo will be able to tell us more about the reception of the 2 recommendations later this week when presenting his chairman's report.

The **Military Low Flying Bird Strike Working Group** with Jürgen Becker as chairman was left with 3 recommendations:

1. The BSCE members should urge the appropriate national authorities to investigate the possibility of contributing to a dedicated multi-national system for the detection and reporting of actual data concerning medium and high intensities of bird migration.

2. The BSCE members should urge the appropriate national authorities to provide warnings (BIRDTAM) as well as bird movement forecasts which are available also for civil transport and general aviation.

3. The BSCE members should urge national air staffs and Air Traffic services to consider/reconsider how the warnings and forecasts can be obtained by pilots without delay and loss of information according to national necessities.

Concerning the first recommendation, the NATO Standardization agreement STANAG 3879 F "Bird Strike Risk/Warning Procedures (Europe)" is now ratified by 10 countries, but only 4 countries (Belgium, Denmark, Germany and The Netherlands) are regularly distributing BIRDTAM/Bird Risk Warnings/Bird Migration Warnings to other countries.

Concerning the second and third recommendations, bird strike warnings of the above-mentioned 4 countries plus France are in principle at the disposal of civil aviation. The transformation of the warnings into operational procedures is a national problem, and can only be recommended by the Working Group.

The main activities of the Working Group were carried out in two meetings of the military expert group "Bird Hazard at Low Level" held in the Hague, The Netherlands, in November 1990 and in Traben-Trarbach, Germany, in September 1991 with participants from Belgium, Canada, France, Germany, Israel, The Netherlands, Norway, and the United Kingdom. The recommendations refer to an improvement of the Military Bird Strike data base for a detailed assessment of the bird strike risk, the improvement of the radar observation network with respect to electronic assessment and calibration of radar data (in close connection with the activities of the Radar Working Group) as well as the issue and standardization of bird strike warnings (BIRDTAM). This will further have as a result that the two working groups will meet together tomorrow.

Next comes the **Remote Sensing of Birds Working Group** with Luit Buurma as chairman. This group was left with the following recommendations:

a) BSCE members should urge national authorities to encourage the appropriate military and civil personnel to evaluate the capability of radar and other remote sensors to monitor bird presence and bird movements.

b) BSCE members should join attempts to further develop the electronic assessment and calibration of remote sensor output with respect to the bird hazard.

c) BSCE members should continue to cooperate with industry in the development of small, dedicated, commercially available bird-observaion radars in accordance with the principles described in the BSCE radar booklet.

d) BSCE members should encourage the use of Geographical Information Systems (GIS) when quantifying the density, identity and potential hazard of bird movements, particularly at the lowest flight levels.

Some of the achievements of the Working Group I have already mentioned when going through the report from the Military Low-Flying Bird Strike Working Group, and it will be mentioned when I come to the activities of the Bird Remains Identification Working group, but I would add that establishing a good joint database has made it possible to analyze 1471 helicopter bird strikes, so far only from 3 countries, the German Air Force, the Royal Air Force and the Royal Netherlands Air Force over about 10 years. The result will be presented during the next European Rotorcraft Forum in September in Avignon.

Next comes the **Bird Remains Identification Working Group** with Tim Brom as chairman.

This Group was left with the following recommendations:

1. That the acting chairman of the BSCE Bird Remains Identification Working Group develop a checklist to inform Accident investigators of the steps necessary to ensure that bird strike as a possible accident cause is not overlooked and any evidence is properly protected and handled.

2. That the chairman should exchange information with which he is familiar on activity so as to prevent expensive duplication.

In the field of bird remains identification a round-table discussion took place during the 20th International Ornithological Congress in Christchurch, New Zealand, 2 years ago and convened by Luit Buurma and the chairman of the Working Group with the title "The problem of collissions between aircraft and birds - involvement of biologists." During this session, Buurma made an introduction to the bird strike problem in general and to the results obtained in radar studies whereas Brom demonstrated the necessity and the possibilities of

identification methods. An important sentence taken from the abstract in the ACTA 20th congress international reads. At least 2 critical aspects should attract biologists' attention: Sophisticated identification of species involved in bird strikes and the understanding of spacial and temporal distributions of birds in the air, including methods of monitoring these movements. Ornithologists from all continents have attended this round-table in New Zealand and it no doubt was a success. Buurma will expand on this item later on.

On the programme of the next International Ornithological Congress in Vienna 2 years from now, various aspects of the bird strike problem will be scheduled.

Next comes **Testing of Airframes and Engines Working Group** with Jean-Pierre Devaux as chairman. Unluckily I was told last Friday that the chairman was unable to attend the meeting, but to our great relief, Ralph Speelman from the USA has agreed to take up the post as acting chairman. This group was left with the following recommendations:

BSCE members should:

a) Encourage the studies on composite materials bird strike resistance.

b) Analyse the influence of transparency systems bird strike impact on the structure adjacent parts, with particular emphasis on vibrations.

c) Send information on the state of the art technology used for protecting all parts of an aircraft in order to edit a BSCE Guide of Airframe and Engines Protection. This guide will also include airworthiness regulations and tests methods used.

d) Encourage studies about "substitute bird" to replace real birds in testing.

e) Seek information on the retention of bird strike capability after extended in service usage of airframes and engines.

A meeting within the group at Saclay Test Center in March 1991 to have discussions on the substitution of real birds as test projectiles by other non-living projectiles was cancelled due to the Gulf War and it was also impossible at that time to visit the bird strike test rig devoted to civil qualification tests.

The chairman of the group has been in touch both with the American and the Russian experts. The group is still without a vice-chairman, but I hope that a sollution to this problem will be found at this meeting.

Last, but not least, comes the **Statistics Working Group** with John Thorpe as chairman, and I can inform you as follows on the progress on meeting recommendations from BSCE 20 in Helsinki:

a) That a poster be developed by the Steering Committee of BSCE to inform pilots, airport personnel, aircraft mechanics etc of the need to report bird strikes and to ensure that any remains, including feathers, are properly identified.

- **Progress**

At the Frankfurt, July 1991, Steering Committee meeting this was discussed and the need for a BSCE logo prior to the production of a poster, was identified. It is intended that the BSCE logo will be discussed during this meeting in Jerusalem.

b) That civil BSCE members are urged to provide the Working Group Chairman with an analysis, or analyses, covering the years 1986-1990. The data should be sent to the Working Group Chairman by September 1991 so that a paper can be prepared for the March 1992 meeting.

- **Progress**

During the autumn of 1991 the Working Group Chairman wrote to all those involved in producing civil statistics and requesting the five years data be consolidated into one document. By the end of January 1992 he was very pleased to have received data from Belgium, Denmark, Finland, France, Norway, Sweden and the UK which was complete including aircraft movements, damage etc. and these countries are to be congratulated on a job well done. Incomplete information has been received from a few other countries. It is hoped that at the Statistics Working Group meeting it will be possible to agree measures to obtain the remainder of the data such that the consolidated 1986-1990 data can be published in Proceedings of the Meeting.

c) That the military BSCE members urge that the Royal Netherlands Air Force work on Military Data analysis be continued in co-operation with Air Force Flight Safety Committee Europe (AFFSC(E)).

- **Progress**

This co-operative work is proceeding and will be fully described at the Working Group Meeting.

Significant bird strike accidents

In civil aviation a Boing 707 freighter was destroyed after over-running the runway at Addis Ababa when a bird was believed to have been ingested during the take-off run. The crew escaped. In December 1991 a Piper Navajo crashed i nKenya after striking a vulture, the 9 occupants were killed. A number of military aircraft losses have occurred, including af UK Air Force Harrier on a low level flight which struck black headed gulls rising from a field being ploughed. Details of other accidents will be discussed at the Working Group Meeting.

Finally, I shall turn to the relations between BSCE and other international organizations. Regarding **ICAO** we regret that this organization has not answered our Invitation Letter.

Jochen Hild, however, has been invited to participate in a workshop on reduction of bird hazard to aviation planned to be held in the South American region in a few months' time, and to participate in an ICAO workshop in Bangkok in a 2 months' time.

Regarding **ECAC** and more specifically its **Technical Committee**, I did not consider it necessary to be present at the meeting, but dispatched a working paper on the activities of our Committee and have been told that it was well accepted.

Regarding **EEC**, I have nothing to report concerning the EEC Directive on bird conservation.

In my capacity of Scandinavian representative in the Regulations Committee of the **Joint Aviation Authority** organization, I have been informed that this organization also has work going on regarding ingestion of birds and I will take care that the work within this Committee and especially of the Working Group Testing of Airframes and Engines is brought to the knowledge of the Joint Aviation Authority.

Finally, regarding **IATA**, we have as always noticed with pleasure the interest IATA has shown towards our work, and I welcome the presence of pilots both as representatives from IATA and as members of the various national delegations.

Finally, I would like to inform you that the 22 BSCE meeting will be held in a two years' time in Vienna in Austria in August 1994, and that there is a good possibility that the 23 BSCE meeting will be held in the United Kingdom.

With these words I wish for all of you a successful meeting.

Chairman's report
Aerodrome Working Group

1. Recommendations from the Helsinki Meeting

This Working Group was left with two Recommendations from the Helsinki Meeting of May 1990.

a. **Recommendation 1990**

BSCE members from EEC countries are urged to ask the appropriate authorities to take into account, when dealing with applications for grants, that changes in land use may affect the potential birdstrike problem at a neighbouring aerodrome and that consultation with aviation authorities and aerodrome authorities might be desirable.

- **Progress**

In the Working Group meeting this was discussed and the proporal to the Plenary Meeting is to delete from the text the words "from the EEC countries".

b. **Recommendation 1990**

The BSCE members should draw the attention of the appropriate authorities to the existence of expert systems to integrate bird data, weather data and control methods. These systems will provide critical information for new personnel assigned to bird control and will assist management in scheduling efforts.

- **Progress**

The Working Group realized that this is self-evident and therefore not worth remaining as a Recommendation. The Working group proposes to the Plenary Meeting to delete this Recommendation.

2. Working Papers Presented at the 21st Meeting, Jerusalem

WP 27 Bird Strike Preventive Maasures in Israeli Air Force.

WP 10 The Potential of Lumbricide Chemicals for Use in Airfield Bird Control.

WP 12	Biotechnical Devices of Bird Scaring.
WP 39	Ultrasonics as a method of Bird Control.
WP 41	Evaluation of Shotgun Shooting to Reduce Aircraft Strikes by Laughing Gulls at John F. Kennedy International Airport.
WP 11	The Influence of Tide and Wind on the Birdstrike Hazard at Coastal Aerodromes.
WP 36	Food Preference of the Chucker Partridge and Domestic Pigeon at Military Aerodromes in Israel.
WP 20	Note on the Performance of the Bird Control Service on French Airports.
WP 32	Aviation Community at Rome International Airport of Fiumicino. A Study for Better Facing Bird Hazard.
WP 16	Determination of Number of Collisions Between Aircraft and Birds to Control Risks of Erroneous Judgements on the Birdstrike Hazard.
WP 37	Risk Analysis of Bird Strikes on Vienna Airport.

3. Aerodrome Working Group Recommendations

1. BSCE members are urged to ask the appropriate authorities to take into account, when dealing with applications for grants, that changes in land use may effect the potential bird strike problem at a neighbouring aerodrome and that consultation with aviation authorities and aerodrome authorities is essential.

2. BSCE members should draw the attention of the appropriate authorities to the outcome of the following studies:

   a. A scientific study conducted in the UK has shown

      - that a fully long grass policy is the mest management technique for deterring birds from airfield grassland,
      - that largescale treatment of grassland by lumbricide chemicals is likely to result in a number of difficulties in terms of the effective application of the chemical on the long grass swards,
      - that the use of lumbricide chemicals may be appropriate on grass areas which are routinely cut short, particularly if problems are encountered with worms moving onto runways in wet weather,

      - that care should be taken if lumbricides are applied to ensure that bird which may be attracted to the area to feed on dead or dying invertebrate are adequately dispersed, and
      - that the routine application of pesticides as an "insurance" against the ap pearance of seasonally abundant insects that may attract large numbers of bird species should be discouraged.

   b. A study conducted in the USA by the USAF Bird Strike Reduction Programme has shown that ultrasonic bird repelling devices do not significantly affect the behaviour of birds and will not work to keep birds away from an area attractive to them.

3. BSCE members should draw the attention of the appropriate authorities to the fact tha when deciding a funding of bird strike measures, the cost of the measure must not be the decisive parameter.

4. BSCE recommends that the French BSCE members describe in detail the informatior considered necesary to improve the organization of aerodrome bird control. It should be sent to the Chairman of the Working Group who will then try to obtain the above information from the member states of BSCE and prepare a working paper for discussion in the view of a potential harmonization at the next meeting.

5. BSCE recommends that the Aerodrome Working Group prepare a 5th issue of the "Green Booklet" to be presented at the next BSCE Meeting.

Heikki Helkamo
Chairman, Aerodrome Working Group
24 March 1992

Chairman's report
Military Low-Flying Bird Strike Working Group

1. Terms of Reference

Implementation of data concerning bird concentrations and movements with the purpose of developing preventive measures to minimize the bird hazard to low flying aircraft.

2. Recommendations from the 20th Meeting

The Working Group was left with three recommendations from the Helsinki Meeting of May 1990:

a. The BSCE members should urge the appropriate national authorities to investigate the possibility of contributing to a dedicated multi-national system for the detection and reporting of actual data concerning medium and high intensities of bird migration.

- **Response**

The NATO Standardization agreement STANAG 3879 FS "Bird Strike Risk/Warning Procedures (Europe)" is ratified by 10 countries, but only Belgium, Denmark, Germany and The Netherlands observe regularly migratory movements of birds, and are reporting BIRDTAM/Bird Risk Warnings to other countries.

b. The BSCE members should urge the appropriate national authorities to provide warnings (BIRDTAM) as well as bird movement forecasts which are available also for civil transport and general aviation.

Response

Bird strike warnings of the above-mentioned 4 countries plus France are in principle at the disposal of civil aviation. In Germany initial stages were made that civil aviation can benefit from the military warnings and forecasts. In the UK positive experience with radar observations makes it possible that in the future bird hazard information can be included in the Low Flying Information System.

c. The BSCE members should urge national air staffs and Air Traffic Services to consider/reconsider how the warnings and forecasts can be obtained by pilots without delay and loss of information according to national necessities.

- **Response**

  Military standing procedures with respect to bird strike warnings are existing in many countries. The transformation of these warnings into adequate operational procedures for civil aviation is a task of Air Traffic Control Services and airlines. The German Federal Office of Air Traffic Control and Lufthansa German Airlines agreed to procedures how military warnings and forecasts can be used by civil pilots.

3. Activities between Helsinki and Jerusalem Meetings

The military participants of the Working group agreed to intensive contact on the prevention of bird strikes during low-level flights. The following expert meetings called "Bird Hazard at Low Level" were held since BSCE 20 with participants from Belgium, Canada, France, Germany, Israel, the Netherlands, Norway and the United Kingdom:

- 6th meeting at RNLAF Air Staff, The Hague/NL, 21-23 November 1990.
- 7th meeting at GMGO, Traben-Trarbach/FRG, 9-11 September 1991.

The results of the meetings are presented to BSCE 21 as WPs.

4. Presentation of Working Papers

The following WPs were presented at the Jerusalem Meeting:

WP 9 The European Database of Military Bird Strikes from Proposal to Reality, presented by A. Dekker/the Netherlands.

WP 18 State of Affairs Concerning the Birdstrike Warning System in Central Europe, extracts presented by J. Becker/Germany.

WP 40 Low-Level Airspace Bird Strike Evaluation and Using a GIS to Integrate Bird Population Dynamics into an Aircraft Bird Avoidance Model, presented by D.J. Rubin/USA.

WP 43 Vultures in Spain by J.C. Manueco/Spain was distributed, but not presented.

WPs 14, 23 and 24 presented by the Remote Sensing of Birds Working Group are also closely related to the Military Low-Flying Bird Strike Working Group.

5. Future Programme

a. The Working Group will highlight the usefulness of a dedicated multi-national system for the detection of bird movements and the dissemination of bird strike warnings with assistance of the European Military Bird Strike Database compiled by RNLAF.

b. The Working Group will initiate improvements of the national observation, reporting and warning systems as well as the exchange of bird strike warnings between different countries.

c. The Working Group will test the usefulness of geographic information systems with regard to spatial and temporal patterns of bird strike risk.

d. The Working Group will make proposals how civil aviation can benefit from the military warning systems.

6. Recommendations

The recommendations from the 20th Meeting were repeated (see item 2).

Jürgen Becker
Chairman, Military Low-Flying Bird Strike Working Group
26 March 1992

Chairman's report
Remote Sensing of Birds Working Group

1. Terms of Reference

Exchange of information on the use of radar and other sensors in the surveillance, identification and the risk assessment of bird presence and movements

2. Activities and Programme since the Helsinki Meeting

Intense discussions on bird detection and its application in favour of flight safety have taken place during intermediate meetings together with the Military Low-Flying Bird Strike Working Group in the Netherlands and Germany (see its Chairman's report). Although the progress with respect to operational application is slow (but continuing), the integration of experiences from several West European countries appears to have a high added value. Real practical progress can be expected from the recent co-operation between the RAF and RNLAF. Also scientific spin-off can be expected to increase as soon as the sophistication of bird echo extraction and analysis improves. An attempt has been made to attract more attention of the world scientific ornithological community to the knowledge gap with respect to bird movements by organizing a well-attended Round Table Discussion during the 1990 International Ornithological Congress in New Zealand.

3. Presentation of Working Papers

As the meeting was held together with the Military Low-Flying Bird Strike Working Group, the Papers have already been mentioned. The following improtant points were raised:

Geographical Information Systems (GIS)

Fully in accordance with the Helsinki Recommendation, the U.S., the Netherlands and Israel are seriously exploring this powerful family of software packages. The challenge is to get reliable spatial and temporal bird distribution data and/or geophysical, meteorological and vegetational parameters indicating bird flying activity. Also there is a matter of scale. A global

approach should start with a low resolution data set while regional (e.g. nationwide) og local (e.g. airport vicinity mapping) initiatives can be very refined and more dynamic. A special topic is the necessity of good cooperation with the conservation oriented ornithologist censussing bird distribution.

The comparison of bird detection results and bird strike statistics

A U.K. trial indicated that peaks in bird flying activity do not always relate to our main concern: real bird strikes. The reason might be less accident prone and/or small birds avoiding or not damaging the aircraft.

Calibration and scale of detection

Radar detection of birds is being done by long range surveillance radars, airfield radars and with small scale tracking radars or ship navigation radars. More or less parallel to this, the detection systems can be parasite systems up to prime users. It was stressed that small scale, but three-dimensional systems become more applicable thanks to increased knowledge, improved calibration and as a result the possibility of extrapolation. Civil aviation may become a market for future dedicated bird radars.

4. Country Reports

Finland. Dr. Stenman regrets not to be able to report progress. The ideally situated Vantaa Airport radar has been replaced by a modern system not suited to detect the intense migration of artic birds. The purchase of a C-band doppler weather radar enabling 3-D quantification of bird movements is under consideration. Contracts with the military side develope slowly.

GOS. As Prof. Jacoby could not attend, Dr. Stenman judged the situation in the Baltic region. The collaboration in respect of monitoring the flyway between the Baltic and the Arctic is hampered due to the political changes. This also includes work previously done in Estonia.

Norway. The former operational use of military radar near Oslo shifted into some experiments and talks about a modern approach. In principle means are available, but key items such as cost-effectiveness, military/civil cooperation and collaboration with other airforces around the North Sea have not yet been worked out satisfactorily. The Norwegian representative asks for more compulsory NATO imputs.

Denmark. The old FAUST system is still working at three air defense radars. There is no programme to test or improve the existing bird warning system.

Germany. The GAF persistently tries to improve the BIRDTAM system in cooperation with neighbouring countries in respect of communication and standardization. Military long range surveillance radars as well as (civil) airport radars are involved, but need (electronic) bird extractors to replace the old photographic method. A cheap intermediate solution through video grabbers is being considered.

Switzerland. Migration over the Alps has been an in-depth study theme since the Fifties in which tracking radars operated by the Swiss Ornithological Institute play a decisive role. The scientific work attracted world-wide attention. Recent improvements in respect of bird data extraction may be important for the operational applications, but so far the Swiss Air Force does not operate a real-time bird detection system. In favour of Airport Munich II a Swiss study on flight altitudes of waterbirds is under consideration.

Israel. Eight years of diurnal bird observation (photographically) at the radar of Ben Gurion Airport in combination with visual observers (real time!) have significantly increased flight safety for the IAF. In recent years female observers also man the radar at night. Several other remote sensing technics have been used experimentally. A Swedish radar (Enterprise) has been purchased for bird detection over the Negev. A similar system is considered for the northern part of the country. A Swiss team is studying the temporal and spatial pattern of bird migration in the Arava Valley in relation to the possible erection of a radio transmitter of the Voice of America.

Italy. As no military representative attended the meeting, there is no clear picture of operational warning systems. A radar test by Selenia revealed only the detectability of large bird flocks at certain altitudes according to a wildlife institute representative.

Spain. No operational use of radar for bird detection exists. Fieldwork on bird migration by foreign scientists is extending. Bad bird strike experience (vultures) by the USAF examplified the potential benefit of bird monitoring systems.

Portugal. No representative. Recent contacts indicate a growing scientific interest in bird migration over Portugal from inside and outside the country.

France. The FAF is considering airport radars as potentials for bird echo extraction and is now an active participant of the Military Low Flying Bird Strike Working Group. As civil aviation exclusively uses secondary radar, it is as yet unable to join the military.

Belgium. The relatively cheap BOSS system at Semmerzake is now part of a radar network claiming to have full 3-D bird detection capacity. Although the Belgian warnings certainly can indicate extreme peaks of migration, the comparison with neighbouring countries asks for calibration.

UK. A trial to relate the intrinsic bird detection capability of all RAF airport radars with real bird strikes (see above and the paper of SqLdr McCloud) may result in a short-term effort to extract bird echoes electronically from the Watchman radar, and in a long-term networking programme possibly in cooperation with the Dutch.

The Netherlands. RNLAF's ROBIN system, in full operation since 1989, will be upgraded in 1993 and then also be able to sample bird movements automatically at highest possible resolution. This will facilitate the development of a prediction model as this model will be fed daily with quantitative real time data per separate bird cohot. Long-term aim is the combination of ROBIN and a small radar into a dedicated bird radar according to the BSCE/Madrid specificaitons. The present warning system has already reduced the "en route" bird strike rate significantly.

USA. Maj. Merritt reported the completion of Dr. Larkin's bird algorithms for the next generation weather radars covering the whole US. However, the NEXRAD project is behind schedule. As no full 3-D capacity may be extected, additional explorations will be initiated. Several small radars have been tested at Dover AFB (Delaware). GIS application is now in the phase of research and discussion with other countries around the world.

5. Recommendations

a. BSCE members should urge national authorities to encourage the appropriate military and civil personnel to evaluate the capability of radar and other remote sensors to monitor bird presence and bird movements.

b. BSCE members should join attempts to further develop the electronic assessment and calibration of remote sensor output with respect to the bird hazard.

c. BSCE members should intensify the contacts with industry in the development o dedicated, commercially available bird-observation radars in accordance with th ciples described in the BSCE Radar Booklet.

d. BSCE members should cooperate with respect to the highly recommended use o graphical Information Systems (GIS) when quantifying the density, identity and pc hazard of bird movements, particularly at the lowest flight levels.

e. BSCE members should verify and evaluate their spatial and temporal bird densi sessments with improved bird strike statistics.

Luit S. Buurma
Chairman, Remote Sensing of Birds Working Group
26 March 1992

Chairman's report

Testing of Airframes and Engines Working Group

1. The Working Group was chaired by Ralph Speelman. This duty was assumed at the request of the Steering Committee in response to their receiving last minute notification that the Chairman, Mr. Jean-Pierre Devaux, would not be able to attend BSCE 21.

2. The meeting was attended by 6 individuals representing 4 countries.

3. An agenda was proposed by the chairman and agreed to by attendees.

   a. Review of accomplishments and related activities in response to Recommendations from BSCE 20.

   b. Working Papers.

   c. Other business.

   d. Recommendations for attention during the period until BSCE 22.

4. **Review of Recommendations form BSCE 20**

   a. **Recommendation:** Encourage studies on composite materials' birdstrike resistance.

   Response: No specific studies of this matter were reported. The need for these studies was recognized, especially with respect to radar radomes. The U.S. did report on a composite frame successfully developed as part of a birdstrike resistant windshield system. The U.K. reported on some composite material patch panels developed to increase the birdstrike resistance of critical structural regions of the aircraft.

   b. **Recommendation:** Analyze the influence of transparency system birdstrike impact on adjacent structure with particular emphasis on the effect of vibrations.

Response: No specific studies were reported on this topic. The U.S. did report that for realistic birdstrike testing of transparency systems it is highly desirable to utilize representative aircraft structure for a minimum distance of about 0.5 meter from the edges of the transparency. This is to allow for adjacent structural interaction.

c. **Recommendation:** Send information on the state-of-the-art technology used for protecting all parts of the aircraft.

Response: Handbooks on birdstrike testing have been produced by the U.K., France and the U.S. These handbooks are representative of early 1980's technology and should be used with caution, as this area has grown quite rapidly. Those needing the latest technology should make contact with the test centres or those routinely applying this latest technology.

d. **Recommendation:** Encourage studies about use of a substitute bird to replace real birds in testing.

Response: The U.S. reported that a series of reports is available on the development and use of an artificial bird. The U.K. reported no a current investigation to quantify the characteristics of a bird relative to its mass and density properties. This will be used in conjunction with computer codes for qualities of engine birdstrike response. The U.S. reported on the development of an analytical model of how a bird acts as a high pressure fluid during the birdstrike event. This model is used in conjunction with computer codes for structural analysis of the birdstrike event.

e. **Recommendation:** Seek information on the retention of birdstrike capability after extended in-service usage of airframes and engines.

Response: No specific studies were reported onthis topic. The U.S. did report on a series of tests currently exploring the structural degradation of cabin window transparencies. These are non-forward facing windows and the testing is to identify characteristics indicative of the transparency having degraded to an unacceptable level of strength, even though it remained optically acceptable.

5. Working Papers

WP 44 "Substitute Bird Objectives and Constraints" by Jean-Pierre Devaux.

The Paper presented a case for use of artificial birds to reduce the problems

created by the need to choose between use of farm birds and wild birds for bi strike testing.

WP 13 "Improving the Birdstrike Resistance of Aircraft Windshields" by Mesrs. Speelm. McCarty and Dversdall.

This report summarized ongoing efforts within the USAF to develop and ap technologies for birdstrike resistance windshield systems which are also optic: acceptable, tolerant of other hazards and are affordable.

6. Other Business

The planned meeting of the Working Group in May 1991 was cancelled due to priorities the Gulf War. It was agreed that the purpose of the meeting is still sound.

7. Recommendations for attention during the period until BSCE 22

a. The attention of the appropriate authorities should be drawn to the cost to civil a military aviation resulting from the low birdstrike resistance of radar radomes.

b. Work should be encouraged which will result in realistic definition of lateral and longit dinal spacing of birds in flight. This information is needed by the airframe and engi design community and for use in establishing airworthiness criteria.

c. Discussions and analyses on the need for birdstrike requirements for light aircraft a helicopters should be supported.

d. Emergence and application of new criteria for airframe and engine certification shou be monitored to encourage standardization.

e. Work should be encouraged which will result in a realistic artificial bird for use in testi of bird impact tolerance.

f. Work should be encouraged which will result in a better understanding of the crite which would result in removal from service of components which have a reduction birdstrike resistance.

Ralph Speelman
Acting Chairman, Testing of Airframes and Engines Working Group
26 March 1992

Chairman's report
Bird Remains Identification Working Group

1. History

During the 17th Meeting of BSCE (Rome, October 1984), it was decided to form a sub-group on the identification of feather remains. At the next meeting (BSCE 18, Copenhagen, May 1986), this sub-group - within the Analysis Working Group - had its first meeting with about 15 members in attendance. During BSCE 19 (Madrid, May 1988), this sub-group convened for the second time. Considering the growing interest in the methods of identification, the participants made the suggestion to the Steering Committee that the sub-group should be raised to working group level. The meeting agreed on this recommendation and as a result the Bird Remains Identification Working Group was formally established in 1988. This new BSCE Working Group had its first ordinary meeting during BSCE 20 (Helsinki, May 1990) which turned out to be very sucessful with 21 participants from 11 countries. In Jerusalem we had the second official meeting of our Working Group and also this was a successful one.

2. Goals and Terms of Reference

During BSCE 18 (Copenhagen) and BSCE 19 (Madrid), the two major goals of the sub-group on feather identification were

a. to pursue the work on the identification of bird remains, with emphasis on the microscopic examination of feathers, and

b. to facilitate the exchange of information pertaining to identification methods, both between countries, between organizations and between ornithologists, and to make an inventory of who are performing the identification of bird remains in each country.

When the Bird Remains Identification Working Group was established, the following Terms of Reference were adopted:

"Exchange of information on the methods used and the results obtained on identification of bird remains."

At the Steering Committee meeting in Frankfurt on 23 July 1991, it was agreed to change the

Terms of Reference of BSCE and the objectives of our Working Group are summarized under litra a of item 4 (see WP 2 from this meeting).

3. Recommendations from BSCE 20

At our last meeting (BSCE 20, Helsinki 1990), this Group was left with two recommendations which were adopted by the Plenary Meeting:

"a. That the acting chairman of the BSCE Bird Remains Identification Working Group develop a checklist to inform accident investigators of the steps necessary to ensure that bird strike as a possible accident cause is not overlooked and any evidence is properly protected and handled.

b. That the chairman of the BSCE Bird Remains Identification Working Group should exchange information with which he is familiar on activity so as to prevent expensive duplication."

4. Events and activities between BSCE 20 (Helsinki) and BSCE 21 (Jerusalem)

a. *European Centre for the Identification of Bird Remains (1990)*

At BSCE 20, a proposal was made to establish a European Centre for the Identification of Bird Remains (see pages 223-234 and 681-685 in the Proceedings from the Helsinki meeting). I can inform you that this Centre has been formally established at the Zoological Museum Amsterdam and that the Royal Netherlands Air Force has signed a 5-year contract with the Centre. Of course, other organizations, authorities or countries are free to continue the identification of bird remains through their national centres, but those interested to participate in the Centre are invited once again.

b. *20th International Ornithological Congress (1990)*

During the 20th International Ornithological Congress (Christchurch, New Zealand, December 1990), a round-table discussion, convened by BSCE representatives L.S. Buurma and T.G. Brom, took place entitled "The problem of collisions between aircraft and birds: Involvement of biologists". The abstract in the Acta XX Congressus Internationalis Ornithologici reads: "Collisions between aircraft and birds are a matter of growing concern owing to trends in aircraft design (lighter components, less noisy and

energy consuming, but more critically built engines), aircraft costs and flying operations (higher speeds at lower altitudes). This is not parallelled by increased involvement of sound biological knowledge. We ask for a discussion on the mutual interest of biology and flight safety. At least two critical aspects should attract biologists' attention: Sophisticated identification of species involved in bird strikes, and the understanding of spatial and temporal distributions of birds in the air, including methods of monitoring these movements."

During this round-table discussion which was attended by ornithologists from all continents, Buurma presented an introduction to the bird strike problem in general and to the results obtained in radar studies, whereas Brom demonstrated the possibilities of identification methods.

c. *Preparations for the 21st International Ornithological Congress (1994)*

The Standing Committee on Applied Ornithology, set up within the International Ornithological Congress in 1986, will schedule various aspects of the bird strike problem during the 21st International Ornitholocigal Congress in Vienna in 1994 as well. Relevant to our work is the fact that a round-table discussion (convenors: Dr. H. Ouellet and Dr. J. Wattel) has been accepted into the programme, entitled "Identification of Bird Remains: The Diagnostic Value of Taxonomic Characters".

5. Working papers

This meeting of the Working Group was attended by 20 participants from 8 countries. The following working papers were presented:

WP 4 Uri Frank and Tim G. Brom (The Netherlands):
"The Diagnostic Significance of Thickened and Prolonged Hamuli in Feathers"

WP 6 S.M. Satheesan and Robert B. Grubh (India):
"Bird-Strike Remains Identification in India"

WP 22 K. Perremans (Belgium):
"The Diversity of Featherprints in the Charadriiformes and the Anseriformes"

WP 26 M. Hansen (Denmark):
"A Method of Identifying Bird Species from a Bloodstrain or Shred of Tissue"

It is encouraging to see that different ways of bird remains identification are being explored and developed.

6. Checklist for accident investigators

The recommendation following the Helskini meeting regarding a checklist for accident investigators was discussed and the text under item 7 was agreed upon.

7. Recommendation

The BSCE members should draw the attention of the appropriate authorities on the existance of the following checklist for accident investigators:

a. Unless there is any definite reason to suspect otherwise, bird strike should always be considered a possibility. Therefore, always check for bird remains following any accident.

b. A determined search for bird remains should be made as soon as is practically possible, to avoid the possibility of contamination by feathers from elsewhere.

c. Do not disregard small remains. Subsequent microscopic or biochemical examination may reveal the presence of feather scraps which will give a clue with respect to the species involved.

d. Bird remains may be found anywhere on the aircraft, not just the frontal surfaces.

e. Collect all bird remains, however small, but keep samples from different locations in accurately sealed and labelled bags. It may be that more than one species was hit.

f. When an on-site search is not possible, components should be covered when in storage to prevent contamination from, for example, pigeons inside the hangar.

g. In case the bird remains cannot be submitted immediately to specialists for identification, keep them in a sealed plastic container in a refrigerator, preferable deep-frozen. This is recommended in particular when flesh or blood fragments are present. If it is not possible to refrigerate, separate feathers from flesh as much as possible to prevent putrefaction.

Dr. Tim G. Brom
Chairman, Bird Remains Identification Working Group
26 March 1992

Chairman's report
Statistics Working Group

1. Recommendations from the Helsinki Meeting

The Working Group was left with three Recommendations from the Helsinki Meeting of May 1990:

a) That a poster be developed by the Steering Committee of BSCE to inform pilots, airport personnel, aircraft mechanics etc. of the need to report bird strikes and to ensure that any remains, including feathers, are properly identified.

- **Progress**

At the Frankfurt, July 1991, Steering Committee meeting this was discussed and the need for a BSCE logo prior to the production of a poster, was identified. It is intended that the BSCE logo will be discussed during the final Plenary.

b) That civil BSCE members are urged to provide the Working Group Chairman with an analysis, or analyses, covering the years 1986-1990. The data should be sent to the Working Group Chairman by September 1991 so that a paper can be prepared for the March 1992 meeting.

- **Progress**

During the autumn of 1991 the Working Group Chairman wrote to all those involved in producing civil statistics and requesting the five years data be consolidated into one document. Austria, Belgium, Denmark, Finland, France, Norway, Sweden and UK are complete including aircraft movements, damage etc. and these countries are to be congratulated on a job well done. Incomplete information has been received from a few other countries. At the Statistics Working Group meeting it was agreed that those other countries would send the data so that the consolidated 1986-1990 data can be published in the Proceedings of the Meeting.

c) That the military BSCE members urge that the Royal Netherlands Air Force work on Military Data analysis be continued in co-operation with Air Force Flight Safety Committee Europe (AFFSC(E)).

- **Progress**

  This co-operative work is proceeding and will be fully described at the Low Level Working Group Meeting.

Significant bird strike accidents

In civil aviation a Boing 707 freighter was destroyed after over-running the runway at Addis Ababa when a bird was believed to have been ingested during the take-off run. The crew escaped. In December 1991 a Piper PA 31 Navajo crashed in Kenya after striking a vulture, the 9 occupants were killed. A number of military aircraft losses have occurred, including a UK Air Force Harrier on a low level flight which struck black-headed gulls rising from a field being ploughed. (See also para. 2(a)).

2. Papers Presented at the 21st Meeting, Jerusalem

a. WP 31 "Serious Bird Strikes to Civil Aircraft 1989-1991" was presented by J. Thorpe, UK. The paper provided brief details of selected serious incidents. A number of significant events were described including a second fatal accident in Kenya, involving a Cessna 402 which killed 7 people. An accident to a prototype 2-seat trainer in February 1992 had killed the test pilot in an accident near Santiago, Chile - there had been 3 fatal accidents to General Aviation Aircraft in 3 months.

b. WP 4 "Bird Strike Problems in Ethiopian Civil Aviation" by Dr. V.E. Jacoby and B.M. Zvonov, Russia, was briefly described by the Working Group Chairman as the authors were not present. It is hoped that the full paper will be published in the Proceedings.

c. WP 17 "Determination of the Total Flying Time Required for Testing the Performance of a new on-Airfield Bird Strike Prevention Strategy against the Standard One" by V.D. Illyichev, Russia, and V.Y. Biryukov and N.A. Nechval, Latvia. This statisticcal paper was briefly described by the Working Group Chairman as the authors were not present.

d. WP 21 "PICA - A Bird Strike Information Program" by A. Eudot, France. This presentation demonstrated on a portable Personal Computer a system for the storage and analysis, in BSCE format, of bird strike data.

e. WP 35 "Bird Strikes on Ben Gurion Airport 1982-1991" by Jerry Yashon and Eyal Shy. This presentation covered the statistics, environment and control measures.

Discussion and questions on the Paper revealed that there were 3½ people full-time on bird control at the airport and at the garbage dump, 6 km away. Crops growing on the airport were controlled, but were allowed within 50 metres of the runway centerline. The airport strike rate was about 1 per 2,500 flights. There were few flights on the Sabbath and the patrol only operated if called out. Radio control model aircraft were used at the garbage dump, one of them armed with shell-crackers. They were flown for 13-14 minutes at a time to harass the gulls which were particularly bad in winter. The very bad weather this winter had driven gulls form the sea into the standing water around the airport.

Black kites did not respond well to shell-crackers, but appeared to be interested and came to see what was going on. It seemed loud music or noise, e.g. RAP music, caused them to move away as if they believed their prey was being frightened. Attempts to close the garbage dump had not yet been successful.

f. WP 42 "Bird Strikes to US Air Force Aircraft 1987-1991" by Major Ron Merrit, USAF. The number of strikes, aircraft losses and data on strikes were detailed. One aircraft loss resulted from at pilot avoiding a bird, but crashing into the sea. After a double engine damage case on a C5A Galaxy legal measures were under way to prevent landfield sites within 10,000 ft (3,048 metres) of any USAF runway. Discussion on windshield/canopy strength requirements highlighted the philosophies on aircrew ejection and the inability to eject through a very bird-proof canopy. A question on the relationship with ATC revealed that in the RAF all new ATC controllers spend a week with the Bird Patrol, it <u>also</u> being a useful way of the controller getting to know the airfield.

g. WP 38 "A Simple Risk Model for Assessing Bird Strike Risk Potential" by Major Ron Merrit, USAF. The risk model is being used to show the airbases with

a high hazard potential based on the aircraft type, bird species, and local attractants. These were the bases that sould be more frequently inspected.

h. A USAF BASH Team video introducing the Bird Strike Problem to new pilots was shown.

3. Other Items and Discussion

a. Military Data and Aircraft Losses were deferred to the Low Level Working Group as this was now being handled by their Chairman through AFSC(E).

b. The importance of sending data to ICAO for input to the IBIS System was emphasized. This data was important as many European airlines operated world-wide and gave an idea of bird problems in parts of the world where there was no reporting by local airlines.

c. The poster to advise "Report All Birdstrikes" as well as "Get Feather Remains Identified" was discussed. The poster was to be a "Master Copy" for states to add their own countries' address for reporting etc. It was dependent upon an agreement on a BSCE Logo.

d. The need to send the information on strikes by airlines of other countries, that occur at airports in your own country, was stressed.

e. It was agreed that those countries which had not yet been able to send a paper containing 5 years of data "1986-1990", would provide this as soon as possible. The information from those countries which had sent data showed that 425 engines had been damaged in the 5-year period, a serious safety hazard and cost. The Working Group Chairman asked whether there was a need to continue with this type of analysis; the Working Group fully supported the continuation of this work.

f. A question about where the data should be sent, to the Contact Person named in WP 3 or to the individual dealing with the matter, was raised. See Recommendation c.

g. The Working Group supported the need for better design requirements for general aviation aircraft and helicopters, particularly on the windshield.

4. Recommendations

a. That the work in producing over-view analysis of data in BSCE format be continued.

b. That those countries which had not yet sent a Paper containing the 1986-1990 data send it to the Working Group Chairman as soon as possible hopefully for inclusion in the BSCE 21 Proceedings.

c. That information on civil strikes should be sent to the person in each country reqponsible for the work rather than the one person named in WP 3 as the contact for each country (see the Attached List).

John Thorpe
Chairman, Statistics Working Group
24 March 1992

LIST OF ADDRESSES FOR CIVIL BIRD STRIKES

The addresses below give the appropriate person who should be sent a copy of bird strikes reported:

- in your country to aircraft from the other country
- to aircraft on your register which have a birdstrike in the other country.

Austria

Mr Klaus KRIZIWANEK
Federal Ministry of Public Economy
and Transport
Radetzkystrasse 2
A-1030 Vienna

Tel: +43 222 71162, ext 9316
Fax: +43 222 7130326
Telex: 61-3221155

Belgium

Mr Marc HAERYNCK
Civil Aviation Administration
CCN 4th Floor
B-1210 Bruxelles

Tel: +32 2 2121211
Fax: +32 2 2176284
Telex: 22715

Denmark

Mr Hans DAHL
Civil Aviation Administration
Box 744
Ellebjergvej 50
DK-2450 Copenhagen SV

Tel: +45 36 44 48 48 ext 275
Fax: +45 36 44 03 03
Telex: 27096 caa dk

Finland

Mr Reijo LAMBERG
Civil Aviation Administration, Finland
PO Box 50
SF-10531 Vantaa

Tel: +358 0 829 2843
Fax: +358 0 870 2304
Telex: 121247 avia sf

France

Mr Jean-Luc BRIOT
Service Technique de la Navigation
Aerienne
246 Rue Lecourbe
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Fax: +33 40 43 47 92
Telex: 202 887 F

Germany

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Deutscher Ausschuss zur Verhutung
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D-5580 Traben-Trarbach

Tel: +49 6541 18203
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Ireland

Dept of Tourism, Transport & Communications
Civil Aviation Division
Kildare Street
Dublin 2
Ireland

Tel: +1 78 9522
Fax: +1 763350/763455
Telex: 91806 TMTT EI

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Dr Carlo LUZZATTI
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Direzione Generale Aviazione Civile
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I-00144 Roma/Fiumicino

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Fax: +39 6 8553720
Telex: LIJJ YA I 613080

Netherlands

Mr Sietze JAGER
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UK

Mr John THORPE
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Aviation House
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Minutes of the Plenary Meeting 23 March 1992

1. Opening of the Meeting

The meeting was opened by the Chairman followed by an introductory video presented by Y. Leshem, Israel.

2. WP 2, Terms of Reference of BSCE

The Chairman presented WP 2 containing a revised version of the Terms of Reference of BSCE as agreed upon during a Steering Committee meeting on 23 July 1991.

The meeting approved of the revised version of the Terms of Reference which will appear in the Invitation Letter to BSCE 22.

3. WP 3, Contact Persons Regarding Bird Strike Work

The Chairman presented the WP and asked the participants to the meeting to inform him of any changes or errors before the end of April 1992.

A revised WP 3 will then be included in the Proceedings from the meeting.

4. WP 8, Bird Strike Hazards to Helicopters

L. Buurma, the Netherlands, presented WP 8, Bird Strike Hazards to Helicopters, and informed the meeting that collisions between helicopters and birds recently have been discussed within the European Rotorcraft Forum in relation to JAR 27 and JAR 29. This has caused the RNLAF to analyze her Alouette-III and Bolkow-105 bird strike statistics with respect to flying hours and the weight of the birds concerned. The high ratios compared to civil statistics used so far has stimulated RNLAF to explore the newly formed European Military Bird Strike Database and to ask for experiences of NATO partners. An over-all rate of 5.4 bird strikes per 10,000

flying hours for 10 helicopter types (N=1471) was found, including 7-29% damage cases. The risk of serious accidents is estimated to be higher than 10^{-6}. Different helicopter types showed persistently differring figures. Explanations for these differences have been questioned. The empirical quantitative data may affect the decision-making within the Helicopter Airworthiness Study Group.

J. Thorpe, UK, indicated that the method of operation of most civil helicopters was very different from the operation of military helicopters. The latter tend to be operating or practising as if they were on a battlefield whereas civil helicopters, especially the larger ones, operating in the North Sea oil environment do in fact operate like civil aircraft. Even the bigger helicopters used for transportation of troops tend to operate as if they were on a battlefield flying behind the natural contours. That could explain the difference in the strike rate between military and civil helicopters. He knew of only one fatal accident involving civil helicopters which was in Canada when a Bell Jet Ranger was doing a sheep count and struck a raven which smashed the windshield. He finally mentioned that the speed of the helicopter and the forward noise of the helicopter most likely would influence the strike rate.

To a question from J. Allan, UK, as to the advisability to use historical data and cumulative bird strike frequencies over a long periode not taking into account how flight routes, types of aircraft, standards of bird control in aerodromes that may change over the years, might influence the data, L. Buurma explained that there were no trends in the Dutch or in the German air force database. For the future it might be different. The reason could be an increased use of more mobile helicopters such as the Apache helicopter which would act on more spots using surprise and attack and flying at faster speeds.

J. Allan, UK, agreed and mentioned that the UK work on the civilian database for fixed-wing aircraft has shown many variables to the effect that it was felt quite unreliable to make predictions on the basis of that kind of data.

J.L. Briot, France, mentioned that France has made a study with bird strike concerning civilian helicopters registered all over the world and covering 500 incidents. The French study showed the same results as the study mentioned in WP 8 and he suggested that there was a need to combine the outcome of the two studies.

L. Buurma informed the meeting that this combination would take place at the forthcoming Avignon meeting of the helicopter people and stressed the need to come up with the data, because the JAR 27 and JAR 29 requirements are under preparation.

5. WP 7, Migratory-Bird Strikes to Aircraft in India

S.M. Satheesan, India, presented WP 7 and mentioned that India merely serves as a destination or land route for several species of migratory birds. From bird strike remains 13 migratory bird species have been identified during the period 1966-1991. The plant and animal food available to birds and the open, large and tranquil aerodrome areal which provide the safety needed by the birds while feeding, resting and nesting, are almost irresistable attractions. The Bombay Natural History Society and the airport authorities supported by the Aeronautics R & D of India have endavoured to make the aerodrome environments ecologically unattractive to birds and in this way reduce the bird strike risk.

J. Thorpe, UK, observed that 30% of the bird strikes had occurred during night hours notwithstanding the fact that only a small proportion of the flying takes place during night hours and that birds of prey in general do not fly at night.

S.M. Satheesan suggested that the bird strikes during night time could involve non-migrating birds.

J. Thorpe, UK, considered the problem of birds of prey, such as the black kite, a serious problem, because over half of the world is affected by this and because unlike bird species such as gulls and lapwings, no means so far have been found.

J. Allan, UK, considered it merely a problem of money as the bird-of-prey problem mostly existed in the developing world.

The Chairman considered that the right place to draw the attention of the bird strike problem involving birds of prey would be in the ICAO workshops, such as in South America where they had the black eagle and in Bangkok.

Y. Leshem, Israel, mentioned the black kite bird population in Nairobi Airport and suggested that arranging a garbage dump some place outside the airstrip could move the black kites outside the airport.

J.L. Briot, France, mentioned that the French administration had had good results in firing 20,000 - 30,000 shell crackers in the southern part of France and also at Dakar Airport in Africa to scare away the black kite.

6. WP 19, Collecting Effort and Identification Standards in Relation to Bird Strike Statistics

T.G. Brom, the Netherlands, presented WP 19. In the WP different methods of

feather identification are discussed and evaluated, such as macroscopical comparison with bird skins, microscopical examination of feather structure, and biochemical analysis of feather proteins. The results of the microscopical investigation of feathers as applied to bird strike analysis in the Netherlands are evaluated. It is demonstrated in which way accurate identification procedures may affect bird strike statistics. The main conclusion is that proper identification of bird remains is fundamental and essential to bird strike statistics. Aviation authorities should direct their effort towards the improvement of the general reporting and collecting standard, whereas biologists should optimize and standardize their identification methods, advertise the possibilities of different identification techniques, and make their expertise available.

To a question from S.M. Satheesan, India, T.G. Brom answered that he had not studied bat hair as the problem of strikes with bats did not exists in the Netherlands adding that there did exist identification keys for bats and that there had been performed some studies on mammalian hairs.

To a question from J. Thorpe, UK, T.G. Brom answered that birds could be identified from their feet. He added that small birds are appearently not struck by engines as small bird remains go straight out of the bypass of the large fan engines and never make a mark. L.S. Buurma, the Netherlands, observed that small birds present a danger for small engines like some military engines in aircraft. Experience has shown that remains from small birds have been found in engines from consecutive bird strikes and after several bird strikes, a problem like spontaneous stall of the engine might occur.

7. WP 25, Predicting Regularity of Bird Migration in Global Bottleneck Areas, on a Daily, Seasonal and Yearly Scale, and its Implementation in Israel Air Force and Civilian Flight

Y. Leshem, Israel, presented WP 25 indicating that the strategic location of Israel, at the junction of three continents, made it a "bottleneck" area into which significant portions of the world population of soaring birds converge. The study used a combination of five different methods to gather data, with each method complementing and confirming the data from the others. The appearance times of migrating raptors and storks was found to be very precise. Variations in migrating routes on a daily, seasonal and yearly scale were also found to be very regular. The results of the study have been implemented in the Israel Air Force and in the civilian

flight system. Procedures for limiting flights during the migration seasons have reduced the average yearly damage to aircraft by 88% compared to the past, while permitting low altitude flights during days with light migration.

8. WP 33, Recent Publications on Birds and Aviation

J. Thorpe, UK, presented WP 33 which contains brief details of publication on birds and aviation produced since the previous BSCE Meeting in May 1990. Details of each publication and its availability were mentioned. The Paper was divided into Research, Bird Control Measures, Statistics and Engine Studies. He urged participants to the meeting to provide him with other publications before the end of April this year in order that a revised WP 33 be included in the final Proceedings.

9. WP 34, An Annotated Bibliography of Bird Hazards to Aircraft

J.J. Short, USA, presented WP 34 indicating that a centralized information bibliographic source would be useful to bring together studies that can be reviewed and serve as a starting point for additional research. The working papers of BSCE, along with articles published in scientific journals and proceedings from workshops sponsored by other states or international agencies, form the majority of what is known about bird hazards to aircraft and what can be done to reduce bird-aircraft interactions. A project to produce an annotated bibliography of bird hazard-related research is underway in cooperation with the U.S. Air Force Civil Engineering Agency's Technical Information Center. Compiling this information in an easily accessible document would assist bird hazard researchers, worldwide. A magnetic format for the bibliography is planned that will facilitate keyword searches and will provide a comprehensive summary of research. He solicited BSCE to provide input and expertise during the development of the bibliography.

To a question concerning what type of keyword system to be adopted, J.J. Short answered that keywords would have to be input at some point in a database for that citation that would show whether a paper, not provided with a keyword had something to do with bird control or bird management or electronic or ultrasound. In using BSCE proceeding papers, highschool or college students who are learning librarian functions, could be asked to review the paper to be finally scrutinized by trained people to make sure that the keywords in the bibliography references and citations are correct. J.J. Short added that this keyword system should be

considered very flexible if a magnetic database was used instead of a hard document or micro-fiche, because it allows one to change keywords. A major problem is to find a compromise between splitting up and lumping again. J. Thorpe, UK, mentioned a UK database that was hierachically structured so that it is both split and lumped at the same time with the ability to get added either way. He suggested that J.J. Short volunteered to read all the papers and do all the keywording which J.J. Short accepted as much as possible in order that a more refined paper could be introduced at BSCE in a two years' time.

The Chairman mentioned that a somewhat similar idea had been presented ten years ago by a delegate from the Netherlands. The Chairman at that time, Mr. Turesson from Sweden, accepted that he should study the problem and come up with a solution. It was discussed in the Steering Committee before the Rome meeting in 1984 and at that meeting it was agreed that BSCE should confine itself to the working papers presented at the bird strike meeting and so it has been since. From the Rome meeting an onwards, BSCE has issued an Index of Papers which of course could be refined. As the paper was not presented before the beginning of the meeting, he suggested that the Steering Committee should study the proposal contained in WP 34 and come back to it in a two years' time adding that at the request of J.J. Short he would take care to forward to him copies of BSCE Proceedings covering the first 8 meetings.

The meeting agreed to the proposal of the Chairman that the Steering Committee study the proposal contained in WP 34 more thoroughly and present a working paper on that subject for BSCE 22.

10. Proposal for BSCE Logo

J. Thorpe, UK, deplored the fact that after 20 meetings BSCE still did not have a logo. He considered it important to have a logo so that on posters and hand-out material this logo could be printed and he asked participants to the meeting to sketch down ideas for logo in a few days' time so that the Steering Committee meeting on Thursday could produce a draft logo to be decided upon on the Plenary Meeting on Friday.

11. WP 28, Radar Studies on Bird Migration in the South of Israel

B. Bruderer, Switzerland, presented WP 28. Radar information on the directions and

the temporal and spatial distribution of bird migraton was requested for an expertise concerning the building of a large antenna system for Voice of America in the Arava Valley. Besides the primary task, the project was supposed to provide information for bird strike prevention in the Israeli Air Force and to offer unique research possibilities on bird migration in a desert environment. The paper comprises the first description of the digital recording methods used in connection with the tracking radar "Superfledermaus". Qualitative data consist of flight paths and wing-beat patterns of tracked birds. Recording of quantitative data is based on conical scanning at different elevations. It provides information on the spatial distribution of birds in a half-sphere of 5 km radius around the radar. Some results were presented and discussed. The quantitative results of the radar observations will also be used for a comparison with different, more traditional observation methods, such as moon-watching, infra-red, and ceilometer observations.

To a question from J. Allan, UK, B. Bruderer answered that during the highest density migration period you can expect up to one bird per 100 metres and this means or implies that at night birds or most birds do not fly in flocks it being completely different from diurnal migration where birds are together in thousands in one flock. However, some birds also fly in flocks at night, such as cranes, ducks and waders.

J. Allan, UK, deduced from that observation that a multiple engine ingestion is extremely unlikely during night flights.

J. Thorpe, UK, agreed to that, because the majority of flying takes place at daylight, but in 10-15 years' time air travel was going to double with the result that the airspace and the sky being of the same size, a lot of flights were going to take place at night and that could result in more bird strikes during night flight.

L. Buurma, the Netherlands, mentioned a report concerning a huge dense nocturnal migration in the Mississippi Valley with the result that an aircraft had several collisions during one night when landing at an airport.

To a question from C. Alfiya, Israel, as to the difference between the density or the number of birds in Sde Boker in the west and the number of birds in the Arava, B. Bruderer explained that it was only in the last days of September where the densities at Sde Boker were higher than at the Arava and the reason could be that at Sde Boker there were north-west winds while on the Arava there were north-north-east winds so that the birds had been drifted from the coast towards the mountain at the edge of the Negev towards the Rift Valley, and then they could follow the ridges which passed near Sde Boker.

12. Cooperation with International Organizations

The Chairman regretted the fact that ICAO was not able to be present at BSCE 21, but mentioned that at the ICAO workshop meetings in the developing countries, BSCE members could offer help, especially regarding the bird collision problem concerning birds of prey. Regarding ECAC, he informed the meeting that ECAC received a report every year on the work going on for presentation at ECAC's Technical Meeting. Regarding IATA, he was pleased that representatives from the airlines were present at the meeting.

L.S. Buurma, the Netherlands, mentioned that in 1990 the International Ornithological Congress took place in New Zealand with some discussion about bird hazard. He participated in this meeting and informed the Ornithological Congress on the work going on in BSCE. He found it necessary that the scientific world be stimulated to hear about BSCE problems and this was achieved by a round-table discussion on bird hazards to aircraft where T.G. Brom, the Netherlands, and he participated. During the same Ornithological Congress meeting there was a revitalization of a standing committee on applied ornithology, the chairmen of which are Hans Berthl and Prof. Ilichev from Moscow. This standing committee has four working groups so far, one of which is the bird hazard group. The idea behind this is that contact should be promoted between ornithologists, scientists in institutes and the aviation world with the idea that a newsletter could be issued containing information on important projects in the scientific world that could have an application in flight safety and developments in flight safety that could be important for the biologists. For the next Ornithological Congress in 1994 in Vienna several subjects related also to aviation were proposed and there will be a symposium, if it is accepted by the organizing committee on the spacial and temporal patterns of birds' flying activity in the air and how to measure it. Further there will be a round-table discussion on microscopic identification and orbit identification technique. He considered the contact with the regular scientific world very important as there was and is a strong tendency among ornithologists to cooperate with bird protection which is also a sort of applied ornithology. He asked the participants to BSCE to bring forward to him ideas with respect to the newsletter and he stressed that this working group was not working for aviation, but had the intention to bring ornithologists closer to application within the aviation field.

Minutes of the Plenary Meeting 27 March 1992

1. Aerodrome Working Group – Chairman's Report

H. Helkamo, Finland, presented the Chairman's Report from the Aerodrome Working Group.

The following recommendations were adopted by the meeting:

1. BSCE members are urged to ask the appropriate authorities to take into account, when dealing with applications for grants, that changes in land use may effect the potential bird strike problem at a neighbouring aerodrome and that consultation with aviation authorities and aerodrome authorities is essential.

2. BSCE members should draw the attention of the appropriate authorities to the outcome of the following studies:

   a. A scientific study conducted in the UK has shown

   - that a fully long grass policy is the best management technique for deterring birds from airfield grassland,
   - that largescale treatment of grassland by lumbricide chemicals is likely to result in a number of difficulties in terms of the effective application of the chemical on the long grass swards,
   - that the use of lumbricide chemicals may be appropriate on grass areas which are routinely cut short, particularly if problems are encountered with worms moving onto runways in wet weather,
   - that care should be taken if lumbricides are applied to ensure that birds which may be attracted to the area to feed on dead or dying invertebrates are adequately dispersed, and
   - that the routine application of pesticides as an "insurance" against the appearance of seasonally abundant insects that may attract large numbers of bird species should be discouraged.

   b. A study conducted in the USA by the USAF Bird Strike Reduction Programme. has shown that ultrasonic bird repelling devices do not

significantly affect the behaviour of birds and will not work to keep birds away from an area attractive to them.

3. BSCE members should draw the attention of the appropriate authorities to the fact that when deciding a funding of bird strike measures, the cost of the measure must not be the decisive parameter.

4. BSCE recommends that the French BSCE members describe in detail the information considered necessary to improve the organization of aerodrome bird control. It should be sent to the Chairman of the Working Group who will then try to obtain the above information from the member states of BSCE and prepare a working paper for discussion in the view of a potential harmonization at the next meeting.

5. BSCE recommends that the Aerodrome Working Group prepare a 5th issue of the "Green Booklet" to be presented at the next BSCE Meeting."

2. Statistics Working Group - Chairman's Report

J. Thorpe, UK, presented the Chairman's Report from the Statistics Working Group.

The following recommendations were adopted by the meeting:

a. That the work in producing over-view analysis of data in BSCE format be continued.

b. That those countries which had not yet sent a Paper containing the 1986-1990 data send it to the Working Group Chairman as soon as possible for hopefully for inclusion in the BSCE 21 Proceedings.

c. That information on civil strikes should be sent to the person in each country responsible for the work rather than the one person named in WP 3 as the contact for each country, see Attached List.

3. Testing of Airframes And Engines Working Group - Acting Chairman's Report

R. Speelman, USA, presented the Acting Chairman's Report from the Testing of Airframes and Engines Working Group.

The following recommendations were adopted by the meeting:

a. The attention of the appropriate authorities should be drawn to the cost to civil and military aviation resulting from the low birdstrike resistance of radar radomes. This will be particularly important when future radars are much more expensive.

b. Work should be encouraged which will result in realistic definition of lateral and longitudinal spacing of birds in flight. This information is needed by the airframe and engine design community and for use in establishing airworthiness criteria.

c. Discussions and analyses on the need for birdstrike requirements for light aircraft and helicopters should be supported.

d. Emergence and application of new criteria for airframe and engine certification should be monitored to encourage standardization.

e. Work should be encouraged which will result in a realistic artificial bird for use in testing of bird impact tolerance.

f. Work should be encouraged which will result in a better understanding of the criteria which would result in removal from service of components which have a reduction in birdstrike resistance.

4. Military Low-Flying Bird Strike Working Group - Chairman's Report

J. Becker, Germany, presented the Chairman's Report from the Military Low-Flying Bird Strike Working Group.

The following recommendations were adopted by the meeting:

a. The BSCE members should urge the appropriate national authorities to investigate the possibility of contributing to a dedicated multi-national system for the detection and reporting of actual data concerning medium and high intensities of bird migration.

b. The BSCE members should urge the appropriate national authorities to provide warnings (BIRDTAM) as well as bird movement forecasts which are available also for civil transport and general aviation.

c. The BSCE members should urge national air staffs and Air Traffic Services

to consider/reconsider how the warnings and forecasts can be obtained by pilots without delay and loss of information according to national necessities.

5. Bird Remains Identification Working Group – Chairman's Report

T.G. Brom, the Netherlands, presented the Chairman's Report from the Bird Remains Identification Working Group.

The following recommendation was adopted by the meeting:

The BSCE members should draw the attention of the appropriate authorities to the existence of the following checklist for accident investigators:

a. Unless there is any definite reason to suspect otherwise, bird strike should always be considered a possibility. Therefore, always check for bird remains following any accident.

b. A determined search for bird remains should be made as soon as is practically possible, to avoid the possibility of contamination by feathers from elsewhere.

c. Do not disregard small remains. Subsequent microscopic or biochemical examination may reveal the presence of feather scraps which will give a clue with respect to the species involved.

d. Bird remains may be found anywhere on the aircraft, not just the frontal surfaces.

e. Collect all bird remains, however small, but keep samples from different locations in accurately sealed and labelled bags. It may be that more than one species was hit.

f. When an on-site search is not possible, components should be covered when in storage to prevent contamination from, for example, pigeons inside the hangar.

g. In case the bird remains cannot be submitted immediately to specialists for identification, keep them in a sealed plastic container in a refrigerator, preferable deep-frozen. This is recommended in particular when flesh or blood fragments are present. If it is not possible to refrigerate, separate feathers from flesh as much as possible to prevent putrefaction.

6. Remote Sensing of Birds Working Group – Chairman's Report

L.S. Buurma, the Netherlands, presented the Chairman's Report from the Remote Sensing of Birds Working Group.

The following recommendations were adopted by the meeting:

a. BSCE members should urge national authorities to encourage the appropriate military and civil personnel to evaluate the capability of radar and other remote sensors to monitor bird presence and bird movements.

b. BSCE members should join attempts to further develop the electronic assessment and calibration of remote sensor output with respect to the bird hazard.

c. BSCE members should intensify the contacts with industry in the development of small, dedicated, commercially available bird-observation radars in accordance with the principles described in the BSCE Radar Booklet.

d. BSCE members should cooperate with respect to the highly recommended use of Geographical Information Systems (GIS) when quantifying the density, identity and potential hazard of bird movements, particularly at the lowest flight levels.

e. BSCE members should verify and evaluate their spatial and temporal bird density assessments with improved bird strike statistics.

7. Chairmen and Vice-Chairmen of the Working Groups

The Chairman of BSCE informed the meeting that H. Helkamo, Finland, during a meeting in the Steering Committee two days ago had announced that he would not be able to continue as chairman of the Aerodrome Working Group. Unfortunately the vice-chairman of the Aerodrome Working Group, Marc Haerynck, Belgium, had not been able to attend the meeting. On behalf of the Steering Committee the Chairman proposed that Marc Haerynck be elected chairman of the Aerodrome Working Group pending the approval of his authorities and that Olavi Stenman, Finland, be elected vice-chairman of the Aerodrome Working Group.

Regarding the Statistics Working Group, the elected vice-chairman has not been able to attend the meeting. On behalf of the Steering Committee the Chairman proposed that K. Krziwanek, Austria, be elected vice-chairman of the Statistics

Working Group pending the approval of his authorities.

Regarding the Testing of Airframes and Engines Working Group, this Group has for some time been without a vice-chairman. On behalf of the Steering Committee the Chairman proposed that Ralph Speelman, USA, be elected vice-chairman of this Group taking into account that most of the both civil and military aircraft flying over the European skies are made in the USA which could warrant election of a non-European to the post.

The meeting agreed to the above-mentioned proposals and it was left to the Steering Committee if the authorities in Belgium and Austria did not accept Marc Haerynck being elected as chairman of the Aerodrome Working Group and Klaus Krziwanek being elected as vice-chairman of the Statistics Working Group, to get other persons to the vacant posts.

8. Mike Kuhring Award

Having explained the background for the Mike Kuhring Award, the Chairman informed the meeting that the Steering Committee at the July 1991 meeting in Frankfurt had decided to confer the 9th Mike Kuhring Award to Werner Keil from Germany in recognition of his long work for the flight safety of the airports and especially for his initiative to organize the meeting in 1966 in Frankfurt am Main where the idea of BSCE was conceived, and for laying the foundation of the Aerodrome Working Group. As Dr. Keil was not present, he asked Jochen Hild, Germany, to receive the citation and deliver it to Dr. Keil.

9. Publicity

J. Thorpe, UK, informed the meeting that he had received 14 suggestions for ideas of a Bird Strike Committee Europe logo and that the Steering Committee preferred the logo from the Israeli authorities provided that the logo is reversed, i.e. the design should go from left to right.

The meeting agreed to the proposed logo.

Next J. Thorpe presented a poster which he promised to send to the authorities outside the UK.

Finally, he presented a small brochure describing why Bird Strike Committee Europe was formed, when it was formed, and giving the names and addresses and details

of Chairman and vice-chairman and with information on the work of each Working Group.

He promised to distribute the brochure to the participants of the meeting.

10. Election of Chairman of BSCE

The Chairman informed the meeting that his term would come to an end after this meeting and that the Steering Committee at its meeting in July 1991 agreed to propose John Thorpe to succeed him. John Thorpe attended for the first time a BSCE meeting in London in June 1972. Already at that time he was appointed rapporteur and later chairman of the working group of what was at that time called the Analysis Working Group, the present Statistics Working Group. At the 19th meeting in Madrid 4 years ago he was appointed vice-chairman and at the 20th meeting in Helsinki 2 years ago he received the Mike Kuhring Award as a recognition of his work for almost two decades for the benefit of flight safety in collecting, analyzing and presenting data and case stories on bird strikes. His work has been of vital importance for the work within BSCE as data illustrated by case stories help decision-makers to understand that even costly measures to reduce the bird strike risk are worthwhile.

The meeting elected John Thorpe as Chairman with applause.

John Thorpe expressed his thanks for the election and promised to do his best to serve the wishes of the Committee and to progress the serious and costly subjects the Committee was dealing with.

In recognition of his long service to the Committee, he presented H. Dahl with a British tankard containing a box of Heineken beer and he also presented a gift for Mrs. Dahl who had attended so many meetings and a gift for his secretary, Mrs. Kirsten Falk Mortensen, who had worked very, very hard indeed between the meetings and at the meetings.

H. Dahl expressed his thanks for the fine gifts and said that he was deeply honoured.

11. Election of Vice-Chairmen

The Chairman informed the meeting that at the Steering Committee meeting in July 1991, the Steering Committee under the assumption that John Thorpe be elected

Chairman, proposed that Luit Buurma, the Netherlands, be elected vice-chairman to succeed John Thorpe in that capacity. Luit Buurma attended the 9th meeting in BSCE in Frankfurt in June 1974. In the 1980'ies, Luit Buurma was elected vice-chairman of the at that time called Radar Working Group and at the 20th meeting in Helsinki he was elected chairman of the working group which is now called Remote Sensing of Birds Working Group. A lot of papers for the BSCE meetings have been issued with Luit Buurma as the author. He would only mention WP 36 from the Helsinki meeting, The Application of Radar for Bird Strike Reduction. The Steering Committee meeting has got the impression that Luit Buurma's capacity goes far beyond the field of remote sensing and consequently the Chairman proposed Luit Buurma be elected vice-chairman.

The meeting elected Luit Buurma as vice-chairman of BSCE with applause.

12. Termination of the Meeting

The retiring Chairman expressed the gratitude to all the participants of the meeting from the Israel Nature Reserves Authority and the Israel Airport Authority for the work that has been done to make the 21st meeting a meeting which, he was sure, would for a long time be kept in the memory of all of the participants. The meeting would be remembered for the very efficient way in which the meeting was arranged and for all the social events which have accompanied the meeting. He mentioned the very early get-together reception Sunday evening, the lunches sponsored by James Richardson Ltd., the El Al Airline and the Aviation Services Ltd., the dinner in the beautiful synagogue and the entertainment with folk dances, the visit to the Israel Museum with the Dead Sea Scrolls and the reception by the Municipality of Jerusalem, the dinner in Tel Aviv and the visit to the old parts of Jaffa, the visit to the historical part of Jerusalem and the dinner and the entertainment at the Hebrew University.

He thanked every person from the host country who had performed all sorts of work and the participants to the meeting for their work and their patience towards him.

His special thanks went to the members of the Steering Committee and to his secretary who as always had been of invaluable help to him.

He informed the meeting that he would retire before the next meeting of the Committee in Austria, but that he would look back upon his work in BSCE since the very beginning almost 26 years ago and especially the last 8 years as one of the

most agreeable parts of his whole working career.

In declaring the meeting closed, he finally indicated that in his opinion the 21st meeting had been a good, successful meeting.